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INDO-PACIFIC FISHERY COMMISSION

COUNTRY REPORTS PRESENTED AT THE FIFTH SESSION OF THE INDO-PACIFIC FISHERY COMMISSION WORKING PARTY OF EXPERTS ON INLAND FISHERIES

Bogor, Indonesia, 24-29 June 1991

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PAPERS CONTRIBUTED TO THE WORKSHOP ON TILAPIA IN CAPTURE AND CULTURE-ENHANCED FISHERIES IN THE INDO-PACIFIC FISHERY COMMISSION COUNTRIES

Bogor, Indonesia, 27-29 June 1991

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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Bogor, Indonesia, 27-29 June 1991

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PREPARATION OF THIS DOCUMENT

This document is the supplement to the Report adopted on 29 June 1991 by the participants at the Fifth Session of the Indo-Pacific Fishery Commission Working Party of Experts on Inland Fisheries, which met in Bogor, Indonesia on 24-29 June 1991. The Supplement contains two sets of edited papers: Part One - Country Status Reports for Inland Fisheries (India, Malaysia, Pakistan, Papua New Guinea, Sri Lanka, and Thailand); and Part Two - Papers presented at the Workshop on Tilapia in Capture and Culture-Enhanced Fisheries in the Indo-Pacific Commission Countries. The Workshop Summary included in the Main Report (FAO Fisheries Report No. 458) has also been incorporated as the last section of this Supplement to give the reader an overview of the main highlights of the Workshop.

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ABSTRACT

This publication contains all the papers presented at the Fifth Session of the Indo-Pacific Fishery Commission Working Party of Experts on Inland Fisheries, held in Bogor, Indonesia from 24-29 June 1991. Part One consists of six country reports: India, Malaysia, Pakistan, Papua New Guinea, Sri Lanka, and Thailand. Part Two presents 12 papers contributed to the Workshop on Tilapia in Capture and Culture-Enhanced Fisheries in the Indo-Pacific Commission countries. The Workshop Summary, which was included in the Main Report (FAO Fisheries Report No. 458), was also incorporated as the last section of this Supplement.

The Workshop highlighted the varying contribution of the tilapias to the fish production of the countries in the Indo-Pacific Fishery Commission (IPFC) region. Tilapias are dominant or prominent in catches from lakes, reservoirs, and backwaters of Indonesia, Malaysia, Sri Lanka, Papua New Guinea, Philippines, and Thailand, where they have been introduced. In Indonesia and the Philippines, they are also produced in cage and pen culture. In India, tilapia has been successful in the southern states. In Bangladesh, tilapia landings from capture fishermen are still rather insignificant compared to total fish production but the fish is considered a potentially good species for culture in view of its ease of rearing, low cost of production, and good profit margins. In Australia, tilapias are considered to be noxious fish and their culture is either prohibited or discouraged in all states except Tasmania.

On the whole, the tilapias, particularly *Oreochromis niloticus*, have become increasingly important in the inland fish production of many countries in the Region, both in capture and aquaculture, and have almost reached the level of importance of cyprinids, the major economically important group of fish. With the introduction of fish cages and fish pen culture in lakes and reservoirs, such as in the Philippines and Indonesia, high yields have been attained at reasonably low costs. Further studies are needed to determine the interaction of tilapias with native species in lakes and reservoirs in the Region. The genetic purity of tilapia strains for future introductions and stocking is also a matter of concern that has to be addressed through further research, possibly in collaboration with international agencies active in the area.

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PART ONE

COUNTRY REPORTS PRESENTED AT THE FIFTH SESSION OF THE INDO-PACIFIC FISHERY COMMISSION WORKING PARTY ON INLAND FISHERIES, BOGOR, INDONESIA, 24-29 JUNE 1991

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INLAND FISHERIES MANAGEMENT IN INDIA: DEVELOPMENT POTENTIAL AND CONSTRAINTS

by

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1. INTRODUCTION

The inland fisheries resources of India are noted as much for their heterogeneity in composition as for their rich production potential. Although it has long been recognized that fish production from inland waters can play a definite role in mitigating the protein deficiency in developing countries, this resource is not contributing to the nutrition of Indian masses to the extent that it should, largely on account of the slow development in the inland fisheries subsector, which could in turn be attributed to a number of factors.

Firstly, development planning has given greater emphasis to marine fisheries, particularly in the earlier years. The lower priority given to inland fisheries is reflected in the public investment made in this subsector: while the fisheries sector received a total of Rs. 27.8 million during the First Five-Year Plan (1951-1956), which increased to Rs. 5465.4 million in the Seventh Plan (1985-1990), a close scrutiny of these plans reveals that until the fourth planning period, only 2.44 per cent of the total outlay for fisheries was allocated for inland fisheries as against the 91.8 per cent for marine fisheries. Even within the inland fisheries subsector, development has focused on aquaculture and allied fields to the detriment of the openwater fisheries. Secondly, the inadequate understanding of freshwater ecosystems and their production functions has led to arbitrary, unscientific, or even irrational exploitation policies. Thirdly, a number of socio-economic constraints hamper inland fisheries development. For example, unlike their marine counterpart, inland fish markets are highly scattered and unorganized, providing little incentive and social support to the fishermen. Out of the estimated 710,000 fishermen in the country, some 490,000 are inland fishermen who live in abject poverty. These fishermen stand to benefit from efforts exerted towards the development of the open water fisheries which, unlike aquaculture, is labor-intensive and has the potential to improve their quality of life.

2. PRODUCTION TRENDS

The present *per capita* consumption of fish in India is a low 3.2 kg/yr against a world average of 12.1 kg/yr and the Japanese consumption of 86 kg/person/yr. Thus, during the formulation of the country's Eighth Plan, *per capita* fish consumption has been targetted at 5 kg/yr. This means that fish production should reach 4.5 million mt, of which 2.1 million mt shall consist of inland fishes, for an equivalent growth rate of six per cent or almost double the 3.2 per cent growth rate during the Seventh Plan period.

The inland fish production of the country was 1.33 million mt in 1988-89 and 1.4 million mt in 1989-90 as against 1.1 million mt at the end of the Sixth Plan period (Table 1). On a state-wise basis, West Bengal has been the consistent top producer, accounting for 34.6 per cent of the total national inland fish production, on the average. Bihar is a far second at an average contribution of 10.7 per cent of total, followed by Andhra Pradesh as a close third at 9.4 per cent of total, on the average.

Table 1
Inland fish production in India (in '000 mt).

States/U.Ts	End of VI Plan	1988–89	1989–90
1. Andhra Pradesh	104.6	122.00	134.43
2. Arunachal Pradesh	0.33	1.50	1.00
3. Assam	48.17	65.50	58.43
4. Bihar	110.00	150.10	156.55
5. Goa	1.35	2.60	2.00
6. Gujarat	23.81	21.50	27.15
7. Haryana	10.01	18.00	20.02
8. Himachal Pradesh	2.70	5.00	4.62
9. Jammu and Kashmir	9.99	11.10	13.00
10. Karnataka	39.63	50.20	55.84
11. Kerala	27.60	26.60	33.31
12. Madhya Pradesh	24.01	54.40	37.96
13. Maharashtra	28.97	45.50	50.00
14. Manipur	5.00	11.80	7.50
15. Meghalaya	0.72	0.80	0.97
16. Mizoram	1.81	2.60	2.81
17. Nagaland	0.45	0.60	0.83
18. Orissa	51.89	69.90	75.87
19. Punjab	3.50	9.10	8.50
20. Rajasthan	16.00	12.00	6.63
21. Sikkim	neg.	0.10	
22. Tamil Nadu	160.00	90.00	75.00
23. Tripura	10.00	16.40	18.18
24. Uttar Pradesh	49.69	90.60	93.47
25. West Bengal	369.51	451.90	512.00
26. Chandigarh			0.04
27. Delhi	2.20	2.50	3.00
28. Pondicherry	1.21	2.30	2.89
Total	1,103.15	1,334.60	1,402.00

Of the total inland fish production, it is estimated that 80-85 per cent comes from capture fisheries (Anon., 1984) and the balance from culture fisheries. Various estimates indicate a potential production from the inland fisheries to be around 2.5 million mt, consisting of 1.56 million mt from freshwater aquaculture in 753,000 ha of available cultivable area (at an average yield of 2000 kg/ha/yr) and about 0.947 million mt from 902,000 ha of brackishwater area (Anon., 1984; Srivastava and Singh, 1984).

These estimates appear to be highly optimistic, however, considering that in the past, the level of utilization of the country's inland water resources has not exceeded 22 per cent in freshwaters (Sarma, 1986) and 5.6 per cent in the brackishwater sector (Anon., 1988). Even if it were assumed that the level of resource utilization by the year 2000 would be an optimistic 50 per cent, only 1.25 million mt of fish can be expected from inland aquaculture. This means that the gap between actual and projected production from inland fisheries has to be met through production from openwater fisheries.

This will not be difficult to achieve considering the wide diversity and extent of the country's inland fisheries resources, and given that the country's fish production systems based on wild and semi-wild fish stocks, constitute the mainstays of its inland fisheries at present and in the years to come. What is needed, however, is for these grossly underutilized ecosystems (i.e., floodplain lakes, reservoirs, and estuarine impoundments) to be managed properly so as to produce yields equivalent to their actual potential. Fishery management of this openwater bodies could be aided by the results of research and pilot-scale studies conducted in the past few decades such as the specific ecology-based management measures which have evolved out of these research and investigative studies.

These notwithstanding, large openwater systems, diverse and dynamic as they are, always pose complex challenges to fishery planners and managers. The common property nature of the resource and the environmental implications of management of openwaters make the job even more complex and challenging.

3. RIVERINE FISHERIES

3.1 Resource Base

India has an estuarine network of rivers and tributaries with a total length of 29,000 km and which carry an average runoff of 167.23 million hectometers representing 5.6 per cent of the total surface runoff of the world. This riverine system is composed of 14 large, 44 medium, and innumerable minor rivers with a total catchment area of over 3.12 million sq km.

3.2 Species Diversity

These rivers are characterized by a highly diverse natural fish fauna. The Gangetic system alone harbors not less than 265 fish species. The Brahmaputra System has 126 species belonging to 26 families. The peninsular rivers have been reported to have at least 76 fish species.

3.3 Fish Yields

Riverine fisheries is a complex mix of artisanal, subsistence, and traditional fisheries with a highly dispersed and unorganized marketing system which frustrates attempts at the collection of regular data on fish yields. Based on CIFRI data collected from selected stretches of the rivers Ganga, Brahmaputra, Narmada, Tapti, Godavari, and Krishna, fish yield varies from 0.64-1.64 mt/km, or an average of one mt/km.

The recent breakthrough in deciphering community metabolism in river ecosystems using the ^{14}C technique has facilitated the quantification of fish yield potential at Kanpur (74 kg/ha/yr), Allahabad (249 kg/ha/yr), and Patna (192 kg/ha/yr) in the river Ganga as against actual yield rates of 24.30, 28.69, and 30.14 kg/ha/yr, respectively. The production potential in the lower Ganga was estimated at 198.28 kg/ha whereas the actual fish yield was 30.03 kg/ha, indicating that only 15.15 per cent of the potential is presently harvested. In the middle stretches, the utilization of the potential is marginally better than in the lower stretches. In the Yamuna, the production potential was estimated at 106.7 kg/ha/yr against an actual yield of 18.91 kg/ha/yr. In general, the potential yield of rivers in India is not fully utilized, suggesting that there is scope for further improvement.

However, as riverine fishes are by nature extremely sensitive to changes in flood regime because of their dependence on seasonal floods for feeding and reproduction; any change in the form and dimension of the flood curve in the rivers is bound to affect the community structure. The productivity pattern in a river is largely governed by the nature and amount of inputs: In the rhithron stretch, the inputs are mainly of allochthonous nature; in the potamon covering the floodplains, the major inputs are silt and dissolved nutrients. The exact relationships between these inputs and the energy and productivity trends in rivers, are still poorly understood.

Thus, the construction of flood control structures and diversion weirs and barrages can lead to a decline in fish yield as a result of the disruption of fish migratory and reproductive patterns, as discussed in further detail in Section 3.4 below.

Studies conducted at the Central Inland Capture Fisheries Research Institute (CICFRI) and elsewhere have also shown that the aquatic community as a whole is highly vulnerable to toxic chemicals and pesticides. The absence of benthos, a decline in plankton population, fish distress and mortality, damage to liver and kidney of sedentary fishes, are some of the harmful effects observed. Heavy metals in the environment get biologically magnified at different levels of food chain: studies in selected stretches of the Hooghly estuary revealed the presence of Zn in the muscles of

15 species of fish and four species of prawn, and the biomagnification of zinc to the level of 640 in crabs, 1,400 in molluscs, 5,610 in prawn, and 6,020 in fishes. Biomagnification of DDT in the aquatic food chain has also been detected, with the indices at different levels being 2,100 (0.130 ppm) in plankton, 4,500 (0.46 ppm) in fishes, 800 in catfishes, and 1,200 (0.960 ppm) in molluscs. Although the rate of heavy metals encountered is less than the human tolerance levels prescribed by WHO, the damage it causes to fish and fish food organisms is being looked into. High BOD values have also been recorded in rivers around big cities of India which are far above the tolerance limit of fishes and fish food organisms.

3.4 Volume and Composition of Fish Catches

The catch statistics over the years indicate some disturbing trends in the riverine fisheries, especially in the Ganga. The biologically and economically desirable species have started to give way to low-value species, exhibiting an alarming swing in the population structure of the Gangetic carps. Fish production from five stretches of the Ganga (*viz.*, Kanpur, Allahabad, Buxar, Patna, and Bhagalpur) has decreased from an average of 95.52 mt from 1961-1969 to 74.5 mt in the 1980s due to environmental changes. A more marked decline has been observed with the highly-prized Indian major carps whose yields dropped from 26.62 kg/ha in 1958-1961 to 14.08 kg/ha in 1961-1969 to six kg/ha in the 1970s and 1980s.

This decline has been attributed to flood control measures and large-scale abstraction for irrigation purposes. In the Ganga basin, 33.5 billion cu m of water are presently held in storage reservoirs behind the weirs and barrages apart from 18 major canal networks diverting water to irrigate seven million ha of agricultural land. These water abstractions and weirs have destroyed a good portion of the carps' breeding grounds, resulting in recruitment failure. Floodplains have also been cut off from the river, converting them into virtual fish traps. Populations of major carps, which are known to retreat to the floodplain oxbow lakes and deep pools during summer, are destroyed either due to drying of the area or to indiscriminate exploitation.

Fish catch composition has also changed, with the increasing dominance of lower-age groups in the commercial catches: In 1976-1983, the fishery was dominated by II-year age groups of *Cirrhinus mrigala*, II and III-year age groups of *Catla catla*, and II-year age groups of *Labeo rohita*.

The once-lucrative hilsa fishery above the Farakka barrage collapsed due to obstruction of the hilsa's migratory path. This is a classical example of physiological strain and breeding failure caused by dams and barrages on migratory fishes. Catadromous migrants like eels, freshwater prawns, and *Pangasius* also seem to have been affected by the barrages.

In the river Brahmaputra in the state of Assam, the fishery in the middle and lower stretches of the river has declined since 1972 and large-scale destruction of brood fishes and juveniles has taken place. In the Godavari, fish yield has been depleted and mahseers, once plentiful in the upstream stretches of the river, are now under threat of extinction.

3.5 Management of Riverine Fisheries

The approach to conservation of fishery resources in India has been guided by *ad hoc* decisions rather than by an objective assessment of factors which determine the abundance of fish stocks and their maximum sustainable yield (MSY). While the management of the riverine fishery on a long-term basis requires a fairly accurate estimate of fish stocks and the prediction of catches, the basic model for studying the production potential of Indian rivers is yet to be developed. A strong data base of deterministic parameters collected over a period of time is the most essential prerequisite for managing the riverine capture fisheries.

4. FLOODPLAIN LAKES

The floodplain lakes which form an integral component of the Ganga and the Brahmaputra basins cover an area of about 0.2 million ha (Table 2).

Table 2
Distribution of flooplain lakes in India, by state

State	River basin	Area (ha)
Arunachal Pradesh	Kameng, Subansiri, Siang, Dibang, Lohit, Dihing, and Tirap	2,500
Assam	Brahmaputra and Barak	100,000
Bihar	Gandak Kosi	40,000
Manipur	Iral, Imphal and Thoubal	16,500
Meghalaya	Someswari Jinjiram	213
Tripura	Gumti	500
West Bengal	Hoogly and Matlah (Ganga)	42,500
Total		202,213

The lakes are important as they regulate the water regime and nutrient exchange, act as natural filters, have vital bearing on the recruitment of populations in the riverine ecosystem, and provide excellent nursery grounds for several fish species and a host of other fauna and flora. A combination of the processes of river bed evolution and the effects of extensive flood control and irrigation works have reduced the production levels of many of these lakes through siltation, habitat destruction, heavy weed

infestation, and isolation from the seasonal floods and natural sources of fish stock. Indiscriminate killing of brood fish and juveniles of commercial species during the recruitment phase badly hampers the production in the lake as well as in the river.

The floodplain lakes, by virtue of their production potential, constitute one of the frontline areas capable of yielding the 1.2 million mt of fish per year targetted in the Eighth Plan since yields of up to 1,000 kg/ha/yr have been attained from floodplain lakes subjected to scientific management. The strategy or approach to adopt in managing floodplain lakes will vary, however, depending on the type or condition of the lake.

For example, lakes with riverine connections are best exploited by keeping the deeper central portions exclusively for capture fisheries and using the margins and pockets for culture fisheries. Capture fisheries would entail monitoring of recruitment and the subsequent growth of the natural populations. In closed lakes, stocking is the mainstay of management, whereas in weed-choked lakes, clearance of weeds and a detritivore-oriented stocking schedule would enhance the yield rate considerably (Yadava, 1987). In some lakes, pen and cage culture operations are possible. Pen culture of major carps in a "macra" in Gandak basin has given a yield of four mt/ha in six months while the culture of *Clarias batrachus* and *Heteropneustes fossilis* in two-sq m cages in a weed-choked *beel* in Assam gave production levels varying from 0.19-4.8 kg after 90 days.

Recent research studies conducted in some *beels* in West Bengal showed that by exploiting the activity coefficient and energy conversion within the system, it is possible to increase energy transfer (E%) at the tertiary level from 0.226 to 0.410 per cent by ecomanipulation. Fish biomass equivalent to 53,520 cal/sq m/yr was harvested from a stocking biomass of around 10,980 cal/sq m/yr.

5. RESERVOIR FISHERIES

5.1 Resource Base

The National Commission on Agriculture (NCA) estimated the total reservoir surface area in India to be three million ha in the mid-70s; this surface area was expected to grow to six million ha by the turn of the century (Anon., 1976). These reservoirs are generally classified into: small (<1,000 ha), medium (1,001-5,000 ha), and large (>5,000 ha). Srivastava and Singh (1984) listed 975 medium and large reservoirs with an estimated area of 1.7 million ha. A Study Group for Inland Fisheries constituted by the Government of India in 1987 identified 420 small reservoirs and 190 medium and large reservoirs for development up to the year 2000 (Table 3).

Table 3
Small, medium, and large reservoirs in India and their production potential

Category/ Area (ha)	Number	Total area (ha)	Production potential
Small			
50 – 100	250	15,000	30,000
101 – 250	100	18,000	27,000
251 – 500	50	17,500	17,500
501 – 1000	20	14,000	11,200
Sub-total	420	64,500	85,700
Medium and Large			
1001 – 2000	168	25,200	126,000
2001 – 5000	12	–	–
5001 – 10000	3	–	–
10000 and above	7	253,000	17,134
Sub-total	190	278,200	143,134
Total	610	342,700	228,834

The biological potential of Indian reservoirs was not evaluated with sufficient reliability until 1970 when reservoir fish yield stood at an extremely low 5-8 kg/ha/yr (Anon., 1976). It was only starting in 1971 upon the commencement of the All-India Coordinated Research Project on Ecology and Fisheries of Reservoirs by the Central Inland Fisheries Research Institute (CIFRI) that reservoir fisheries research took on a new dimension. Limnology was recognized as an important factor in formulating norms for fish yield optimization from reservoirs. In the course of a decade, the average fish yield from reservoirs increased to 15 kg/ha. These studies also brought about an improvement in technical capabilities and provided some guidelines for change. The remarkable increase in fish yield from 25.56 to 80 kg/ha in Bhavanisagar in Tamil Nadu and from 25 to 76.5 kg/ha in Gobindsagar in Himachal Pradesh are excellent proofs that management strategies can indeed work.

5.2 Reservoir Productivity

By and large, the productivity of reservoirs is influenced by their climatic, edaphic, and morphometric features. The geographic location influences the final productivity through climate, nutritional supply, and basin characteristics. Area, mean depth, and shoreline features form the most significant morphometric attributes indicating productivity.

Through the efforts of CIFRI, over 200 Indian reservoirs have been subjected to ecological and fishery investigations over the last two decades. Using information gathered by these studies, a strong data base on reservoir ecosystems has been established which has made it possible to classify Indian reservoirs according to their level of productivity (*viz.*, low, medium, or high) for management purposes (Table 4). Mean depth, hydrographic cycle, basin morphometry, soil characteristics of both basin and catchment, nutrient budget, thermal and chemical stratification, and oxygen curve have been found to be useful indicators for assessing the yield potential of reservoirs.

Table 4
Physico-chemical features (range of values) of Indian reservoirs

Parameters	Overall range	Productivity		
		Low	Medium	High
Water				
pH	6.5–9.2	< 6	6–8.5	> 8.5
Alkalinity (ppm)	40–240	< 40	40–90	> 90
Nitrates (ppm)	tr–0.93	Negligible	Up to 0.2	0.2–0.5
Phosphates (ppm)	tr–0.36	Negligible	Up to 0.1	0.1–0.2
Specific conductivity (umhos/cm)	76–474		Up to 200	> 200
Temperature (°C)	12–31	18	18–22	> 22
		(with minimal stratification: i.e., >5 °C)		
Soil				
pH	6–8.8	< 6.5	6.5–7.5	> 75
Available P (mg/100 g)	0.47–6.2	< 3	3–6	> 60
Available N (mg/100 g)	13–65	< 25	25–60	> 60
Organic carbon (%)	0.6–3.2	< 0.5	0.5–1.5	1.5–2.5

tr = trace

5.2.1 Energy transformation and fish yield potential

Community metabolism in Indian reservoirs has been studied in some detail. Reservoirs in India differ from one another with respect to incident light energy and its conversion into chemical energy. It has been observed that only 0.2-0.68 per cent of the incident solar energy is converted into chemical energy in these reservoirs. It was further estimated that 41.7-65.2 per cent of the energy fixed by the producers is actually stored in them, the rest being utilized for metabolic activities. The efficiency of energy flow through the food chain culminating in fish yield was found to drastically differ in managed and unmanaged reservoirs.

For example, in Bhavanisagar, the efficiency of energy conversion from primary producer to fish was of the order of 0.28 per cent, while in Rihand, it was only 0.034 per cent. This level of variation is attributed to the quantitative and qualitative variation in the species spectrum of the lakes. The two main pathways through which this primary chemical energy finds its way into the fish are the grazing chain and the detritus chain (Natarajan and Pathak, 1983). The contribution by both pathways to the total availability of the energy is required to derive the species combination most suited to the ecosystem.

Observations made in the abovementioned reservoirs revealed that more energy flows through the detritus chain than through the grazing chain. Only in the case of Rihand, where the fishery is almost entirely based on *Catla catla*, does the energy flow more through the grazing chain. Once the energy pathway is established, appropriate management can ensure a higher rate of energy harvest in the form of fish.

5.2.2 Potential yield and catch and effort

A first approximation of the fish yield potential of a reservoir is of paramount importance before large-scale management measures are taken up. Several methods have been proposed for estimating fish production from lakes and reservoirs using specific assumptions and variables (e.g., Ryder, 1965; Jenkins, 1967; Gulland, 1971; Sheldon *et al.*, 1972; Oglesby, 1977). The morphoedaphic index (MEI), Jenkins' model, Gulland's model, and the trophodynamic model are important techniques for the rapid assessment of lakes and reservoirs. Although the MEI approach has worked for some large reservoirs, its validity has been doubted for shallow and small irrigation reservoirs (Jhingran, 1989). Its efficiency in such waters is reduced in the same proportion as the increase in the ratio of lotic to lentic character of the reservoir (Henderson *et al.*, 1973).

Fish yields vary from one reservoir to another in India: from 94.5-296 mt (equivalent to 25.56-80 kg/ha) in Bhavanisagar; 32.3-190 mt (1.75-10 kg/ha) in Nagarjunasagar; 147.3-328.8 mt (4.89-10.91 kg/ha) in Rihand; and 273-753 mt (25-72 kg/ha) in Gobindsagar during the period 1971-1979 (Natarajan, 1979). Present yields of 76.5, 109, and 85 kg/ha/yr from Gobindsagar (11,200 ha), Ukai (36,523 ha), and Jaisanand (8,120 ha) reservoirs, respectively, suggest that it may be reasonable to target yields higher than 100 kg/ha/yr even from large, deep reservoirs. This may be possible with an increase in fishing effort and/or the introduction of new and more efficient fishing methods or fishing gears.

Management interventions can likewise be adopted to maximize the yield within a given food spectrum, ensuring a higher yield from the more economically important species. In most parts of India, the three Indian major carps *Labeo rohita*, *Catla catla*, and *Cirrhinus mrigala* are the most widely used together to ensure that all the niches in the reservoir are utilized while at the same time giving better economic returns.

Competition for food and space from low-value fish could be reduced by way of using trawl nets or seines of small mesh size. Seines used in Tungabhadra reservoir in Karnataka have been effective in checking and eradicating such fish (David and Rajagopal, 1969). Recently, successful attempts were made in Gandhisagar reservoir in Madhya Pradesh to introduce single and two-boat bottom trawling for eradication of predators and trash fishes and for capturing major carps and other commercially important species. Based on the trials, it was recommended that the two-boat mid-water trawling at three to four knots was more profitable for the exploitation of commercial species, whereas single and two-boat bottom trawling at two to three knots was suitable for eradication of uneconomic species of fishes in reservoirs (Kartha and Rao, 1990).

For successful management of the fisheries of large lakes and reservoirs, it is imperative that new whole-system models relating to yield assessment are developed.[1] Current methods of fish yield estimates at the community or subsystem level require modification or refinement so that yields may be determined with greater precision

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[1]Moreau and De Silva (1991) tested three types of models for inland fisheries of the Philippines, Sri Lanka, and Thailand. Their suitability for Indian reservoirs still needs to be assessed, however. (Ed.)

precision. One significant development that gives some basis for greater optimism is that recent management measures adopted in certain reservoirs have resulted in production levels much higher than have been assumed earlier.

5.3 Small Reservoirs

In contrast to the large multipurpose reservoirs, the small irrigation reservoirs created on small intermittent water courses serve to trap the surface runoff for its abstraction during seasonal irrigation demands. Experience has revealed that these waterbodies offer immense potential for fish husbandry through extensive aquaculture. Considering the urgent need to enhance inland fish production in the country, emphasis is being laid on following a short-term experimental management approach towards reservoir fisheries development. This approach is based on collection of data on key limno-chemical parameters of water and soil, quantitative biology, and efficient exploitation techniques which would provide a clue to the production potential of the ecosystem and would be helpful in setting valid targets of fish production from such waterbodies (Mehrotra and Jhingran, 1986). Some of these guidelines necessary towards formulating fisheries development strategies for reservoirs have already been given by Jhingran (1986).

These management options have been tried in many small Indian reservoirs where yields increased to 140-200 kg/ha/yr. Keetham, a small 259-ha reservoir in Uttar Pradesh (UP) is on record as giving a yield of 530 kg/ha. Subsequently, small reservoirs such as Loni in Madhya Pradesh, Damodar Valley Corporation reservoirs in Bihar, Gulariya, and Bachhra in UP, and Aliyar in Tamil Nadu (TN), were investigated to test the validity of the approach. The results obtained from three of these reservoirs are shown in Table 5.

Table 5
Production trends in scientifically managed small reservoirs in India

Reservoir/Location	Area (ha)	Yield (kg/ha)	
		Before scientific management	*After scientific management*
Gulariya (UP)	150	33	100
Bachhra (UP)	140	*	139
Aliyar (TN)	646	27	202

* New reservoir.

5.3.1 Stocking Policy

Stocking is a useful tool for the management of small reservoirs, particularly those that dry up completely during summer and therefore need to be restocked with fingerlings for the next year's fishery.

The optimum stocking density in small reservoirs is based on the potential yield depending on the basic productivity levels and individual growth rates of the stocked species, giving allowance for natural mortality and the escape of fingerlings through the irrigation canal and spillways.

The flooding of small reservoirs which dry up completely during summer has been compared to the annual flooding of the floodplains. Flooding helps release more nutrients, resulting in high food production through the decomposition of organic matter. In some states in the country, the exposed areas of such reservoirs are utilized for sowing leguminous crops which help in mineralization of the soil leading to higher growth and survival of the fish in the reservoirs. The absence of predators and biologically higher productive status of such reservoirs allow stocking of advanced fry, instead of fingerlings (40-150 mm), early in the season to allow a maximum grow-out period.

5.3.2 Development Strategy

The first step in the rapid assessment of the country's small reservoir resources is the preparation of an inventory of such ecosystems along with estimates of potential yields. These reservoirs are then categorized into those which: (i) are best developed for capture fisheries; (ii) have significant potential for fish culture; and (iii) are intermediate in size and potential yield. The reservoirs may then be substratified in terms of priority based on their basic productivity levels, geographical location, market vicinity, and demand.

The management strategy (strategies) to be adopted in the reservoir will vary on a case-to-case basis. As mentioned in Section 5.3.1 above, those small reservoirs that dry up completely in summer are best stocked regularly with suitable fish species. In waterbodies where the fish are able to breed naturally and produce fry and fingerlings (as in the Loni reservoir in Madhya Pradesh where the major carps have been observed to breed above the spillway), the spillway and the canal mouth have to be screened to prevent the escape of fingerlings and adults into the irrigation canals and increase fish yields. It would also be economically advantageous to adopt an annual cropping policy whereby the reservoirs are stocked in September-October and harvested by end-June to allow a rearing period of eight to ten months.

Aquaculture can also be practised in small reservoirs, either alone or in combination with livestock-raising or crop farming in the fringes or exposed areas of the reservoir. Livestock husbandry or crop farming can contribute to soil fertility to the benefit of aquaculture, and at the same time increase food production and provide additional income to the rural communities living around the reservoir.

6. ESTUARINE FISHERIES

6.1 Resource Base

The various estuarine systems in India cover an area of over 2.7 million ha. The estuarine fisheries are above the subsistence level and contribute significantly to total production, with their average yield of 45-75 kg/ha. The important estuarine resources of the country and their production levels are shown in Table 6.

Table 6

Important estuarine fisheries resources of India

Estuarine system	Estimated Area (ha)	Production level (mt)	Major fisheries
Hooghly–Matlah estuarine system	2,340	20,000–26,000	*Hilsa, Harpodon, Trichiurus, Lates,* prawns, etc.
Godavary estuary	18,000	approx. 5,000	Mullet, prawns
Mahanadi estuary	3,000	approx. 550	Mullet, *bhetki,* sciaenids, prawns
Narmada estuary	30,000	approx. 4,000	*Hilsa,* mullets, prawns
Peninsular estuarine systems *(Vasista, Vinatheyam, Adyar, Karuvoli, Ponniar, Vellar, Killai, and Coleroon)*		approx. 2,000	Mullets, prawns, clupeid, crabs
Chilka lagoon	103,600	approx. 4,000	Prawns, mullets, catfishes, clupeids, perches, threadfins, sciaenids
Pulicat lake	36,900	760–1,370 (20.6–37.2 kg/ha)	Prawns, mullets, perches, crabs, clupeids
Vembanad lake and Kerala backwaters	50,000	14,000–17,000 (fishes) (280–366 kg/ha) 88,000 (live clams) 170,000 (dead shells)	Prawns, mullets, *bhetki,* pearlspot, *Chanos*
Wetlands of West Bengal			
Freshwater *bheries*	9,600	10–14 (1,258 kg/ha)	Prawns, mullets, tilapia, *bhetki*
Saline *bheries*	33,000	approx. 25,500 (775 kg/ha)	
Mangroves	356,500	no data available on catch	

The Hooghly-Matlah estuarine system, Chilka lagoon, Adyar and Mankanam estuaries, Pulicat lagoon, coastal belt of East Godavari, Vembanad lagoon, and Mandovi estuary, have been identified to be excellent sources of naturally occurring fish and prawn seed for use in aquaculture. In the recent past, there has been a specific decline in the salinity of the Hooghly-Matlah estuarine system due to the regulated discharge from the Farakka Barrage. This has brought about distinct changes in species composition apart from natural fluctuations caused by density-dependent and density-independent factors.

As the country looks forward to its emerging coastal zone management needs, guidelines evolved at the CICFRI provide valuable insights and possible solutions for the beneficial use, protection, and sustainable development of the country's estuaries, following a holistic approach (Jhingran and Chakrabarti, 1990).

6.2 Hilsa Fisheries

The hilsa (*Hilsa ilisha*) fishery in India has almost disappeared from its freshwater strongholds. Whereas it used to contribute a lucrative fishery in the middle reaches of the Ganga river up to 1,500 km above the estuary, its fishery has virtually collapsed, with landings declining by as much as 98 per cent after the construction of the Farakka barrage at 476 km from the river mouth (Table 7), greatly affecting the lives of thousands of fishermen along the riparian stretches in Uttar Pradesh and Bihar.

Table 7
Average landings (mt) of hilsa in the river Ganga in the pre- and post-Farrakka periods

Centers	Pre-Farakka	Post-Farakka
Allahabad	19.30	1.04 (94.61)
Buxar	31.97	0.60 (98.12)
Bhagalpur	3.95	0.68 (83.05)

( ) Percentage of decline

A recent significant development in the hilsa fisheries has been the attempt to practise aquaranching for its revitalization. The CICFRI has been striving to develop hatchery management practices for hilsa and to restock the depleted stretches of the river Ganga with artificially produced seed. Efforts in this direction have borne fruits in 1991 and a sample consignment of hilsa seed has been stocked in the Ganga above the Farakka barrage. This is the beginning of an ambitious plan to set up a hatchery at Farakka and to undertake a regular stocking program for hilsa.

In order to supply stocking material to replenish its dwindling fisheries in rivers and to undertake its culture under controlled conditions, the CICFRI initiated research on breeding and culture of hilsa. Success in the artificial breeding of hilsa was first achieved in 1978-1979 and suitable hatchery systems and nursery practices are being evolved. In culture experiments, the fish reached a size of 325-360 mm in about 28 months.

Notable success has likewise been achieved by CICFRI in the artificial breeding of hilsa in the Hooghly and the Narmada estuaries and the rearing of its young in freshwater habitats. A modified portable plastic-type hatchery has been designed and manufactured for artificial breeding of hilsa. Fingerlings from artificially bred hilsa have been stocked in Utai reservoir in Gujarat. The establishment of a hilsa hatchery and the restocking of depleted river stretches hold considerable promise towards fostering the recovery of the lost hilsa fishery.

7. SOME MAJOR CONSTRAINTS TO DEVELOPMENT AND NATIONAL EFFORTS TO OVERCOME THEM

A number of diverse and complex problems confront inland fishery managers. These constraints can be broadly grouped under four major categories, viz., biological, environmental, socio-economic, and legal.

7.1 Biological Constraints

The extraction of fish riches from the rivers, based on the principle of maximum sustainable yield (MSY), has not been possible in the Indian context as fishing has been guided by economic profit rather than by biological principles. The intensity of fishing, nature of exploitation, and species orientation in the typical artisanal fisheries of Indian rivers are governed by: (i) seasonality of riverine fishing activity; (ii) unstable catch composition; (iii) conflicting multiple uses of river water; (iv) stresses leading to nutrient loading and pollution; (v) lack of understanding of fluviatile systems and poor data base; (vi) fragmentary and outmoded conservation measures lacking enforcement machinery; (vii) inadequacy of infrastructure; (viii) defective marketing and distribution systems; (ix) demand directed by availability, affordability, and palatability; and (x) other socio-economic and socio-cultural determinants.

7.1.1 Stock Assessment

Successful management strategies have to take into consideration the key parameters of hydrology, fish stocks, and population dynamics together with regulatory measures for fishing. In the absence of a tested model of multispecies fishery of Indian inland waters in the past, single-species models were put to use with little success. Empirical and analytical models developed along lines of the Beverton and Holt model were also found to be ineffective in Indian conditions. Efforts are therefore being exerted to develop a suitable Indian model, taking due cognizance of significant interactions quite ubiquitous in the tropics. Significant progress has been made in developing a prey-predator relationship from the catch data and some viable prediction models have been worked out based on biological parameters. CICFRI has built up an impressive database which enables scientists to test various models and develop new ones which are more realistic and suitable for Indian conditions.

7.1.2 National Scheme on Inland Fisheries Statistics

An infirm data base on inland fisheries resources has been one of the serious constraints that has plagued the development process. Even market intelligence statistics suffered from various drawbacks due to the disposal of appreciable quantities of catch that passed directly from the primary producers to consumers.

A Central Sector Scheme was launched during the Seventh Plan to evolve a methodology for collection of data on inland fisheries. The Scheme has already standardized and laid down the concepts, definitions, and terminologies for collection of inland fisheries statistics. The resources have been classified under seven broad groups, namely: (i) freshwater ponds and tanks; (ii) lakes; (iii) floodplain lakes; (iv) rivers; (v) reservoirs; (vi) estuaries; and (vii) brackishwater impoundments. Separate sampling design and estimates have been evolved for rivers, ponds, and reservoirs. Stratified two-stage cluster sampling with cluster villages as first-stage unit and ponds within the cluster as second-stage units has been adopted for the freshwater aquaculture sector. A stratified two-stage sampling design was found suitable for estimation of catch from streams, rivers, and estuaries whereas stratified random sampling was recommended for reservoirs. The Scheme has enlarged its area of operation during the Eighth Plan by adding eight more states, thus covering a total of 16 states in the country.

7.2 Environmental Constraints

Notwithstanding the rather discouraging picture the riverine sector portrays, conservation and management of the biological resources of rivers assume greater significance in the Indian context. Firstly, as the rivers are the source of fish germplasm of all the species employed in aquaculture systems, the riverine ichthyofauna need to be protected as a gene pool. Secondly, the riverine fisheries sector provides employment and the only means of livelihood to a large section of society. Thirdly, the need for an integrated river basin development system of which fisheries is an integral part, has been recognized as an effective mode of rational utilization of water and land resources in the river basins. Some definite steps have been taken in this direction during the last few years, among which the Ganga Action Plan is worth mentioning.

7.2.1 Ganga Action Plan (GAP)

The GAP is a massive national project launched in 1985 with a view to halting and reversing the process of environmental degradation in India's prime river, the Ganga. The main objectives of the GAP are to improve the water quality of the Ganga and its tributaries to acceptable standards and to oversee the implementation of a long-term program for undertaking suitable measures to restore its water quality. GAP is a comprehensive plan comprising control of domestic and industrial pollution of the river, development of the river front, and maintenance of river hygiene and ecology of the basin. It is the first massive plan of this nature in the country and would serve as a model for undertaking pollution abatement works in respect of other rivers as well. For the successful implementation of the Action Plan, scientific input from a large number

of national R&D organizations have been mobilized for the development and application of suitable technologies. More than 25 cities adjoining the river course are covered under 262 schemes of the GAP at a cost of Rs. 3.443 billion.

The major thrusts of the Project are the following:

(i) Survey and identification of pollution loads;

(ii) Treatment technologies with stress on low-cost resource recovery and effluent recycling;

(iii) Pilot plants for new low-cost recycling;

(iv) Low-cost sanitation technologies;

(v) Resource recovery;

(vi) Energy recovery from sewage gas;

(vii) Sewer inspection and *in situ* rehabilitation;

(viii) Flow measurement;

(ix) Water quality modelling;

(x) Water quality monitoring of the river at macro- and micro-levels;

(xi) Industrial waste treatment for clusters of small-scale polluting units and industrial pollution abatement from gross polluters through directives, monitoring incentives, and prosecution proceedings.

Under the Project, some 368 mld of domestic sewage have been diverted through the efforts of GAP up until 1991. The water quality of the river Ganga has shown improvement in 1990 at those stations that completed pollution abatement schemes. Improvement is seen in terms of dissolved oxygen, pH, CO_2, specific conductivity, and biochemical oxygen demand (BOD). Ameliorating effects of the GAP on the riverine environment with a bearing on fish productivity, are clearly discernible in some stretches of the Ganga, especially Kanpur where a significant improvement in the water quality and primary productivity rate have been observed due to the diversion of effluents, along with a corresponding increase in fish production potential. The fish production potential of the river, calculated on the basis of primary productivity, registered an increase from 8-144 to 111-182 kg/ha/yr (Table 8).

Table 8
Ecological changes in the river Ganga due to diversion of sewage effluents at Kanpur

Zone	Before diversion				After diversion			
	1	2	3	4	1	2	3	4
Energy fixed by producers (cal/sq m/day)	4,152	2,968	3,913	222	4,352	3,212	5,309	5,256
Photosynthetic efficiency (%)	0.355	0.254	0.330	0.019	0.372	0.272	0.454	4.50
Fish production potential (kg/ha/yr)	144	103	136	8	151	111	184	182

7.2.2 Mahseer Fisheries Development Project

This Project was set up in Karnataka for the conservation and development of mahseers in the State. Operating under the Western Ghat Programme, this Rs. 16.7-million Project aims at rejuvenating the depleting mahseer fishery of the State. The Project, to be completed in eight years, aims to produce five million fish seed per year for stocking in the depleted river stretches.

7.3 Socio-economic Constraints

The riverine fishermen constitute a section of economically weak, tradition-bound society. Most of them live at a subsistence level or below the poverty line. Environmental degradation and the resultant decline in fish populations threaten to deprive them of a steady catch. The problems are further compounded by stronger competition among fishermen due to an increase in their population. More and more people come to fish in the rivers where the fish is fast depleting. The competition for fishing grounds has resulted in territorial claims of fishermen which prevent them from going far away from the stretch near their village to fish. Social, educational, and economic backwardness make them easy prey of illegal money lenders and middlemen. Institutional finance often eludes the riverine fisherman as he does not fulfill the conventional qualifications in terms of securities, sureties, and collaterals.

7.3.1 Insurance Scheme for Inland Fishermen

Keeping in mind the socio-economic milieu of the traditional fishermen, a new set of yardsticks has to be evolved to assess their creditworthiness. Also, the fishermen who toil in open waters are to be provided with insurance cover, even if it means relaxing existing standards of insurability.

Under a centrally-sponsored scheme being taken up in the State of Karnataka, insurance coverage is being extended to the fishermen who are exposed to the hazards of natural calamities while fishing. The insurance amount payable is Rs. 15,000 in case of death or permanent disability and Rs. 7,500 in case of partial disability. More than 60,000 active fishermen have been insured in the State under this scheme. The premium is shared by the State and Central Governments.

7.3.2 Central Sector Scheme on Marketing

The Government of India, recognizing the lack of market infrastructure as a major deterrent to the growth of the inland fisheries sector, launched a Central Sector Scheme to promote fish marketing in states which are not covered by state-level cooperative federations or state fisheries corporations. The Scheme envisages to float marketing organizations to effectively intervene in the marketing of fish by establishing market infrastructure and cold storage facilities at the state/district level. The Scheme also provides for the price support to begin at the reservoir/river site, pond site, or the riverine landing center.

7.3.3 World Bank-Sponsored Survey

The massive Narmada Development Project comprising 29 major dams and 450 medium and small reservoirs has evoked national and international debate, as the project threatens the lives of thousands of riparian inhabitants, the most vulnerable being the fisherfolk whose traditional source of livelihood is at stake. As one of the essential prerequisites of reservoir development planning is an investigation into the socio-economic conditions under which the proposed Project is to operate, the Narmada Control Authority, in close liaison with the World Bank, sponsored a sociological survey of the fishermen community in the Basin, which was executed by the CICFRI.

The Survey covered a 1,312-km stretch of the river, spanning 17 districts in the states of Madhya Pradesh, Maharashtra, and Gujarat. The Survey identified six districts which are vulnerable to the ill-effects of the Project, affecting the lives of 6,154 fishermen-families. A total of 18,285 men and 15,760 women will lose the opportunity to fish in the river and market the fish. The Khalgat and Maheswar projects will affect the natural breeding grounds of commercially important riverine fishes and threaten the lucrative major carp seed trade. The natural mahseer breeding grounds at Dharampuri will be adversely affected by the Sardar Sarovar Project.

The Survey also described the socio-economic milieu of the fishermen community. The literacy rate among the Narmada fishermen ranged from 18-33 per cent. Among the 24-521 fisher-persons interviewed, 23.51, 7.23, 0.25, 0.04, and 0.15 per cent had primary, secondary, graduate, post-graduate, and technical levels of education, respectively. A substantial number of the fishermen work as unskilled laborers as the income from fisheries is not adequate to sustain them and their families. A majority of the fishermen have benefitted from financial and banking institutions, and cooperative societies have not made any significant inroads into their social life. The Survey report provided baseline information useful in assessing the possible socio-economic impacts of the Narmada impoundments on the fishermen-community, and focused attention on many vital questions that may arise while formulating the rehabilitation programs.

7.4 Legal Contraints

Fisheries legislation in the country is, by and large, guided by the Indian Fisheries Act of 1897 which stipulates the closed season, defines the irrational fishing practices to be prohibited, and limits the minimum size of fishes and the mesh sizes to be employed. Based on empirical knowledge available at that time, this Act can be termed, at best, as a reference material for lawmakers. Fisheries being under the jurisdiction of the state, it is the prerogative of the state governments to frame rules on conservation and management of riverine fisheries resources. Many states in India, like West Bengal, until recently, and the Northeastern states, have no fisheries legislation. Rajasthan enacted fisheries legislation in 1984. Some states like Uttar Pradesh, Andhra Pradesh, Madhya Pradesh, and Kerala have some fisheries regulations but these have played a subordinate role owing to enforcement problems.

The complexity of factors involved in the regulation of fisheries in India stems largely from the following factors: (i) common property nature of the resources, (ii) difficulties in enforcing the limited access concept; (iii) divergent auctioning and leasing policies being followed by different state governments; and (iv) the multiplicity of agencies that control the water resources and regulate environmental parameters. Considering the urgent need for a comprehensive legislation in capture fisheries with special reference to the riverine fisheries of the Ganga, a legal sub-committee has been constituted under the Ganga Action Plan and a draft legislation is being prepared. More emphasis has to be given to the strict enforcement of the legal provisions.

8. SOME IMPORTANT DEVELOPMENT PROJECTS

8.1 *Beel* Fisheries Development Program

A massive scheme for *beel* fisheries development in Assam has been envisaged with financial assistance from the World Food Programme (WFP). The objectives of the Project are to optimize fish yield from the *beels* by adopting culture-based fisheries practices and to conserve the natural populations for development of the capture fisheries. The Scheme encompasses 16 *beels* covering an area of 4,268 ha. Originally conceived in 1988, the Scheme did not take off in time. Among the 16 *beels* coming under the purview of the Project, 75-100 per cent development has been achieved in six *beels* while 50-75 per cent progress has been achieved in five *beels*. The Scheme provides for eco-hatcheries to raise stocking material, deep channeling of the connecting channels, and erection of fisheries estates in the peripheral areas of the *beels*.

8.2 Reservoir Fisheries Development

8.2.1 The National Scheme

A massive national scheme is afoot to develop the reservoir fisheries in the country with international funding. The Rs. 200-million scheme was originally conceived during the Seventh Plan period to be implemented by the National Cooperative Development Corporation (NCDC) in collaboration with the World Bank, the Government of India, and the State governments concerned.

The main objectives of the Scheme are to raise the productivity of 27,200 ha of reservoirs in the states of Karnataka, Gujarat, and Maharashtra from 14.5 kg/ha to the level of 100 kg/ha; to extend the technology to *beel* fisheries of the states where such waterbodies are available; and to generate additional employment in the rural sector. During the Eighth Plan period, the scope of the Project was expanded to include an additional water area of 13,000 ha in Tripura, Manipur, and the other Northeastern states. An additional 10,000 ha of reservoirs in the states of Uttar Pradesh, Orissa, and Andhra Pradesh are being brought under the Project with World Bank assistance. The World Bank also sponsors development of 10,000 ha of small and medium oxbow lakes in Assam, West Bengal, Bihar, and Uttar Pradesh under the Scheme.

The Scheme envisages to increase fish production from reservoirs and *beels* following judicious stocking management; to improve the infrastructural facilities for better management and exploitation of reservoir fisheries; and to improve the conditions of fishermen living in the vicinity of the reservoir projects by suitably strengthening the fisheries operatives. The Scheme will provide direct employment to 78,500 persons in addition to indirect employment opportunities in ancillary activities under the development plan. The Scheme has also a built-in component to protect the habitat from environmental degradation due to developmental activities. One of its main objectives is to bring the fishermen under the cooperative sector to protect them from the clutches of middlemen and money lenders. The states of Karnataka, Gujarat, and Maharashtra will be covered initially.

8.2.2 Reservoir Fisheries Development Agency

There is a growing demand to set up a national agency to coordinate the development of reservoir fisheries, especially by mobilizing institutional finance in the sector. Many meetings and workshops have made recommendations to this effect. Recently, the Workshop on Reservoir Fisheries conducted under the joint auspices of the CICFRI and the Indian Branch of the Asian Fisheries Forum has strongly recommended the creation of a Reservoir Fisheries Development Agency along lines of the existing Fish Farmers' Development Agency (FFDA) to accelerate the pace of development in reservoir fisheries.

8.3 Manpower Development

India has, over the years, developed a remarkable infrastructure of manpower development matching the country's reputation of having the third largest workforce in science and technology. Apart from meeting the training demands at home, these outfits are capable of providing training to other developing countries as well. Fisheries training institutions range from those doing advanced research in the state-of-the-art laboratories to the network of field training centers at the grassroot level. The Central Institute of Fisheries Education (CIFE), Central Institute of Fisheries and Nautical Engineering Technology (CIFNET), and fisheries colleges of various agricultural universities have been instrumental in manpower development in the fisheries sector. The CIFE, besides catering to the in-service training requirements of the State Government officials, also conducts M.Sc. courses in Fisheries Management and Administration. Consequent to its recognition as a Deemed University in March 1989, this Institute is the apex body in fisheries education in the country. Besides these, the *Krishi Vigyan Kendras* (Farm Science Centers) at Narakkal (Kerala), Kakdwip (West Bengal), and Dhauli (near Bhubaneswar) along with the Trainers Training Centers are involved in organizing training programs on both capture fisheries and aquaculture for farmers and trainers.

9. CONCLUSION

The inland fisheries of India is at a critical point in its development. The increasing degradation and loss of fisheries habitats and growing threats to the aquatic ecosystem brought about by fast-changing coastal configurations, wetland loss, pollution, and destructive fishing practices, necessitate the formulation/adoption of a national perspective for the sustainable development of aquatic resources and fisheries.

Aquatic environments in developing countries are especially vulnerable because national priorities for development are often in conflict with the norms of conservation. Development strategies need to have a holistic approach suited to the entire river basin, and a systems approach to development and management needs to be adopted. In the integrated development of multipurpose systems, it should be possible to develop all living resources together, and to link the management of fisheries, forestry, and agriculture with agro-industrial and hydro-electric units, thus facilitating the recycling of nutrients, optimizing river basin production, and minimizing pollution, eutrophication, and toxic contamination consequent to changes in hydrobiological and socio-cultural regimes.

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INLAND CAPTURE FISHERIES IN MALAYSIA

by

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1. INTRODUCTION

The lack of information and the need to review inland capture fisheries in Malaysia as a basis for the enhancement of inland fishery management and resource development, was highlighted in the Report of the Fourth Session of the IPFC Working Party of Experts on Inland Fisheries held in September 1988 in Kathmandu, Nepal.

Until recently, little attention has been paid to the inland capture fisheries of Malaysia and earlier reviews of production levels were based largely on information available from the census or from secondary sources (e.g., Sreenivasan, 1989; Khoo, 1987; Baluyut, 1983). It is therefore necessary to re-examine the status of the inland capture fisheries and to redefine research needs in the light of differences in ecosystem type and difficulties in the collection of statistics on capture fisheries of marginal inland waters. It is also important that primary data generated through scientific research (e.g., fish population studies) be taken into account in this review.

The initiation of a detailed and comprehensive documentation on the inland capture fisheries is very timely considering the existence of the infrastructure for inland fish production and marketing. An in-depth assessment of the present status of the inland fisheries could help direct research towards this long-neglected and low-priority sector, and guide fishery planners and managers in an objective assessment of its scope for future development.

Some of the relevant programs now being pursued by the Government of Malaysia in this sector are the following:

(i) Development of lakes and reservoirs for fisheries production in Malaysia (EEC-Department of Fisheries, Malaysia);

(ii) Riverine and lake fish culture (Sabah);

(iii) Promotion of freshwater fish consumption (Federal Agricultural Marketing Authority, Malaysia); and

(iv) Environmental impact assessment for development projects (with aquatic ecosystems as one aspect).

This review, prepared for the FAO/IPFC Fifth Session of the Working Party of Experts on Inland Fisheries, has adopted the following as Terms of Reference:

(i) To review the present status of Malaysian inland fisheries development;

(ii) To collate and compare the fish yield levels of various ecosystem types, wherever possible;

(iii) To provide sample case studies for subsistence fisheries in inland water bodies of Malaysia including socio-economic and marketing aspects; and

(iv) To discuss and propose research directions in relation to inland capture fisheries.

2. THE INLAND FISHERIES RESOURCES OF MALAYSIA

In Malaysia, inland capture fisheries is carried out in rivers, swamps and floodplains, reservoirs and tidal barrages, disused tin mining pools, ricefields, and irrigation canals.

2.1 Riverine Fisheries

2.1.1 Fish Yields

Malaysia has a total of 94 major river systems consisting of 49 rivers in Peninsular Malaysia, 24 in Sabah, and 21 in Sarawak. Riverine fishing activities take place, although unorganized and scattered, along these main river channels and their tributaries. Occasionally, there are fish landing sites of "kampong" (village) type traditionally established along the river banks. The rural population harvests as much fish as they need for household consumption and fishing is practised on an irregular and leisurely, and/or part-time, basis.

Indigenous carps (Cyprinidae) and riverine catfish (Siluridae) dominate the harvests and contribute significantly towards the riverine capture fisheries in large river systems (Khoo *et al.*, 1987). Assessments of the riverine fishery resources of Malaysia have been rarely carried out as the fishery is artisanal in nature, which somehow prevents complete documentation and full knowledge of the actual production from these fisheries. An appraisal of these inland fisheries resources can be based on published figures of Watson (1982), Ang (1984), and Lelek (1987) for the Sarawak streams, and on the faunistic-ecological surveys of Bishop (1973) and Ahyaudin *et al.* (1987) for Peninsular Malaysia (Table 1).

Table 1

Fish yields of Malaysian rivers, reservoirs, tin mining pools, and ricefields

Type of Waterbody	Yield (kg/ha/yr)	Fish species (No. of species/family)	Method of estimate	Reference
RIVERS				
Rajang, Sarawak	100	60 ; 16	Fisherfolk catch survey + cold–storage capacity	Lelek, 1987
Baram, Sarawak	142–169		Fisherfolk catch survey	Watson, 1982
Baram, Sarawak	60 (if spawning once a year) 726 (if spawning once a month) 242 (if spawning once every three months)		Life history of the fish	Ang, 1984
Gombak, Selangor, Darul Ehsan	180	15 ; 10	Fisherfolk catch survey + Leger–Huet's standing stock	Bishop, 1973
Perak, Perak, Darul Ridzuan	11.64	27 ;5–8	Cast–netting, stratified into day–night catches	Present study
RESERVOIRS				
Bukit Merah Reservoir, Perak Darul Ridzuan	37	48 ; 14	1978–1981 catch survey + resource assessment models	Yap, 1983
Bukit Merah Reservoir, Perak	Average 38 (15.69–60.28)	48 ; 14	Catch–effort of indigenous gears	Yap, 1992
Subang Reservoir eutrophic Selangor, Darul Ehasn	90	12 ; 5	Fisherfolk catch + auto–consumption surveys	Yap & Furtado, 1983
DISUSED TIN MINING POOLS				
Tin mining pools (Perak Selangor, Kedah, etc)	303.03 1795.65	Indonesian carp only; 3 exotic + Indonesian carps	Stock–harvest	Jothy, 1977
Six undrainable pools, Bidor, Perak	3560	Nile tilapia only	Stock–harvest	Present study
RICEFIELDS				
Krian Irrigation Scheme Perak	88.3 174.6	3 ; 3	Rice farmers' harvest	Ali, 1990

* Computation based on raw data from Ahyaudin M. Sadek (1987) reporting total monthly harvest (assuming 30 fishing days per month) of 179 g/night–hour and 173 g/day–hour; radius of cast–net, 2.5 m; three cast–netters making 10 casts per sampling period at three sampling stations at Parit, Perak.

Available information shows that the annual yields of Malaysian riverine fisheries vary widely. This variability may be due in part to the fact that the results were obtained using different stock assessment methods which in turn use different assumptions and have certain basic/inherent limitations (Welcomme, 1983). Within the limitations, the annual fish yield of Rajang River, Sarawak, has been estimated to reach 100 kg/ha (Lelek, 1987) while in the Baram River in Sarawak, yields of 142-169 kg/ha have been attained (Watson, 1982). For a similar environment within Baram River, Ang (1984) estimates a fish yield of 60 kg/ha/yr assuming that the dominant fish species spawn only once a year; 242 kg/ha/yr at a spawning frequency of once every three months; and a higher yield of 726 kg/ha/yr if spawning frequency is once a month.

For Peninsular Malaysia, the estimated yield level of 180 kg/ha/yr for the Gombak River in Selangor is probably attainable and is likely to be landed from the rhithronic headwater streams, while the computed figure of 11.64 kg/ha/yr (Ahyaudin *et al.*, 1987) on relatively-developed or urbanized reaches of Perak River (at the vicinity of Parit) probably reflects the yield level of the potamonic lower reaches of lowland river basins. This latter figure could be an underestimate since it is based on castnet fisheries only; higher yields will probably be obtainable in more intensive studies involving multi-gear fisheries using indigenous materials (Yap, 1983). These examples based on fish population studies, although limited, suggest that the capture fisheries of some Malaysian riverine systems are not yet maximally exploited.

2.1.2 Potentials and Constraints for Enhancement of Riverine Capture Fisheries

Khoo *et al.* (1987) reported the collapse of the riverine fisheries in Malaysia due to pollution, siltation of river systems, damming, illegal use of fishing gears/methods (like poisons and explosives), and overexploitation. Riverine fish resources have been under pressure from these combined activities as manifested by declining catches and poorer species diversity.

Since the negative effects of damming and industrial and agricultural development are identified during the environmental impact assessment (EIA) of a project, it is now possible to somehow minimize these effects through the adoption of early mitigating measures. It is noteworthy that the minimum flow requirements for rivers at all times after construction and impoundment are now being taken into consideration in project planning. For example, river flow is maintained at 5.5-21 per cent of the present river downstream of Babagon Reservoir in Sabah, for a water flow reduction to 10-13.5 ML/d (Yap, 1990a); 66 ML/d for Linggui Reservoir on John River (Yap, 1990b); and 300 ML/d from 5,482 ML/d for Sungai Buboh Dam on Selangor River in Selangor (Yap, 1991a).

The maintenance of minimum flow to flush and discharge polluted industrial and agrochemical effluents was also considered during the early planning stages for Pasir Gudang Industrial Extension Scheme on Johor River (Yap, 1990c), Tumboh Swamp Drainage and Agriculture Development on Perak River (Yap, 1991b), and Krian Swamp Drainage and Agricultural Development (Yap, 1991c).

2.2 Swamp and Floodplain Fisheries

The potamonic lower reaches of Malaysian lowland rivers are flat, characterized by broad streams meandering over extensive floodplains, with scattered swamps and remnants of water-filled depressions (e.g., Krian River and swamps) (Yap and Ong, 1990). With some exceptions, swamps are low-lying and water-logged shallow areas enriched with decaying organic matter, which either retain water either perennially and/or dry up during the dry season. Based on their waterholding capacity, there are three microhabitats of swamps/riparian systems: (i) permanent water-filled depressions which hold water for more than nine months per year; (ii) semi-permanent depressions which hold water for about six months/year; and (iii) transient waterbodies which hold water for about three months per year.

Swamps are characterized as watered areas which are not used for conventional commercial prospects, mainly due to neglect, and are usually categorized as marginal lands, being remote and infertile soils (Petr, 1983). Generally, swamp ichthyofauna, fisheries, and aquaculture are poorly understood and poorly developed although Willoughby (1979) reported that maximum yields from swamp fisheries approximate 60 kg/ha/yr. In Malaysia, although no serious efforts have been made to increase the fishery resources and yields from swampy areas, swamps are intensively fished by traditional fishermen. Predominantly, some hardy air-breathing teleosts with their biological and physiological adaptations abound in such habitats. Fisheries potentials in such marginal waters are thought to be considerable (Furtado and Mori, 1982). Inland fishery production can therefore be considerably increased by proper utilization of swamp habitats, particularly through aquaculture. In India, organic detritus is abundant in derelict swampy waters and can support a sizable stock of air-breathing catfishes such as *Clarias* and *Heteropneustes* spp., producing more than 1.2 mt/ha/seven months without any additional inputs of supplementary feed or fertilizers (Dehadrai, 1980). There are other evidences of increase in fish yields after swamp reclamation. The fish yields from swampy Lake Rawa Pening, Java, Indonesia have increased by about 16 times after reclamation (Vaas and Schuurmann, 1949). Chacko and Abraham (1962) indicated a steady increase in fish production from a swamp near Madras City after its reclamation and stocking. However, it has been shown that the expenditure incurred for the reclamation of swamps can only be recovered after a post-reclamation period of 16-17 years (Mitra, 1956).

In Malaysia, the prospects for enhancing fish production in swamps, riparian systems, and old river beds are limited by the fact that flood control measures, river diversions, or river valley modifications have effectively reduced the areas available for fisheries. For instance, rural development plans of Krian River Basin in Perak propose to reclaim eleven swamps with a total area of about 6,661 ha, representing a reduction of about 94.7 per cent of the total swamp area. Another planned development involves the reclamation and conversion of a total of about 13,000 ha at Tumboh Swamp in Perak into agricultural land (Yap, 1991b).

2.3 Reservoir Fisheries

2.3.1 Inland Reservoirs

Due to its geological past, Malaysia does not have natural lakes; it only has man-made lakes or reservoirs, of which there are nearly 141,000 ha at present.

In Malaysia, the reservoirs are heterogeneous water bodies which vary in size, use, purpose, limnological features, and biological productivity (Table 2; Fig. 1). By virtue of their unnatural origin, there is no truly lacustrine fish species to support and sustain reservoir fisheries. The fish assemblages are riverine species which are able to adapt to the lacustrine (= standing water) conditions, and species diversity has been reported to vary considerably from one reservoir to another, e.g., 12 species belonging to five families in Subang reservoir (Yap and Furtado, 1983), 22 species belonging to six families in Temengor reservoir, (USM, 1983), and 48 species belonging to 14 families in Bukit Merah reservoir (Yap, 1983b).

In these three cases, the Cyprinidae is the most dominant in terms of species number with five cyprinid species representing 41.7 per cent of the total species number in Subang reservoir, 14 species representing 66.7 per cent in Temengor reservoir, and 14 species representing 29.2 per cent in Bukit Merah reservoir. The Anabantidae and Ophicephalidae rank next in importance in these three reservoirs. In Subang reservoir, four anabantid species represent 33.3 per cent of the total species numbers; and in Bukit Merah, five anabantid species represent 10.4 per cent of total species numbers. In Temengor reservoir, two ophicephalid species represent 9.5 per cent of total species numbers. Fish species diversity in different zones within reservoirs has been little studied, except for Bukit Merah reservoir where the following values of species diversity have been recorded for four sub-areal components: inflow, 2.31; outflow, 2.4; spillway, 2.54; and reservoir proper, 3.12 (Yap, 1982).

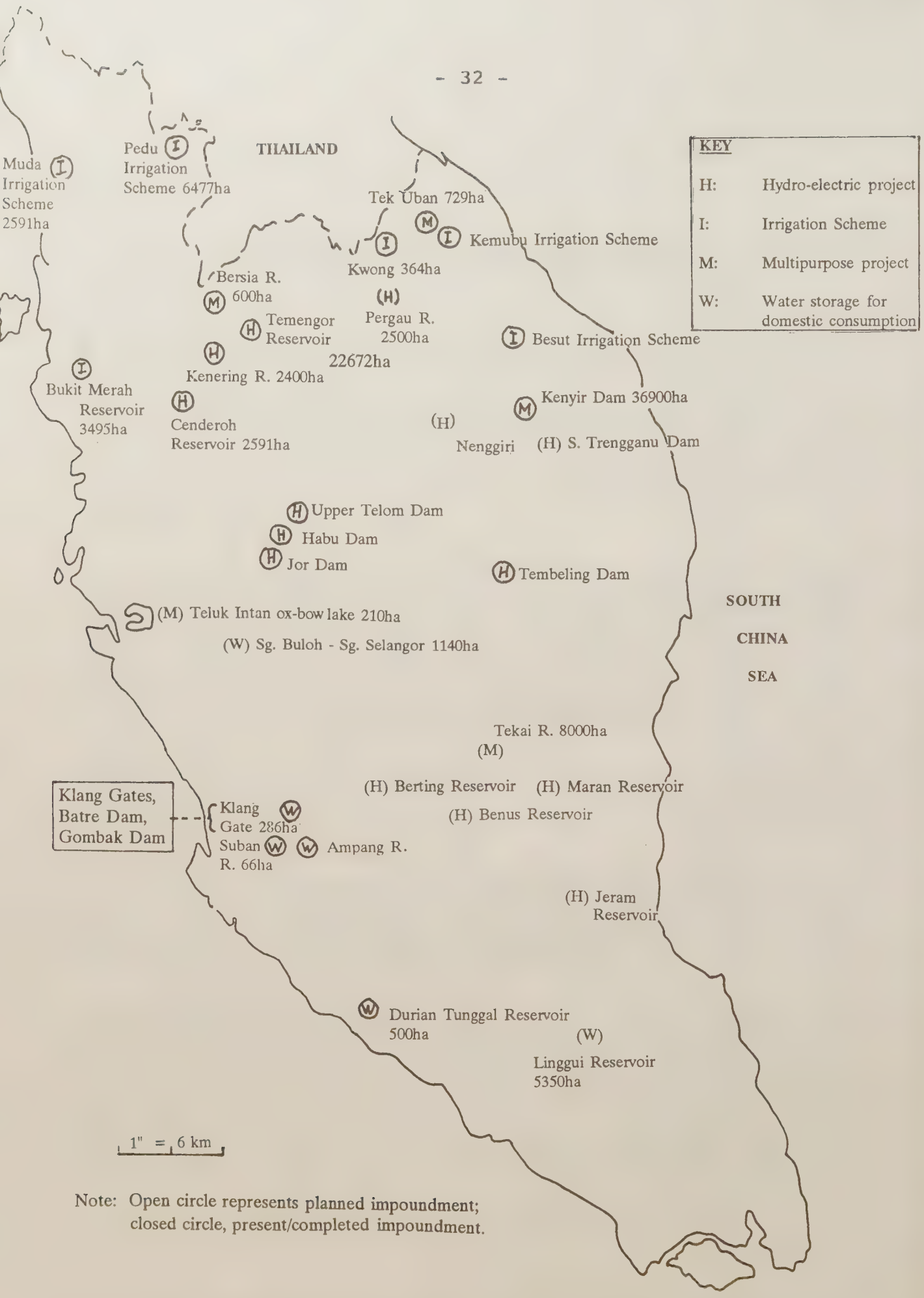
The capture fisheries in Malaysian reservoirs use traditional/artisanal fishing methods and gears consisting of gill nets (50-100 m long and with mesh size of 45-50 cm), cast nets, hook-and-line, stakes, and bamboo traps. Freshwater prawns are caught using a special type of bamboo trap or tray (Yap, 1983a).

The fish production levels of reservoirs in Malaysia can be approximated based on published works on the Bukit Merah reservoir and on the eutrophic Subang reservoir in Selangor (Yap and Furtado, 1983). Using the catch-effort assessment method, the total annual yield from Bukit Merah reservoir was estimated at about 38 kg/ha/yr and ranged from 15.69-60.28 kg/ha/yr (Yap, 1991d). This estimate is close to the 37 kg/ha/yr derived from an earlier catch census of the reservoir (Yap, 1982; Yap, 1983b). The estimated yield from Subang reservoir is 90 kg/ha/yr (Yap and Furtado, 1983).

Table 2

Classification of reservoirs in Malaysia and ranking according to surface area at upper storage level (USL)
(based on the recommendations of the Second Asian Reservoir Fisheries Workshop, Hangzhou, China, 15-19 October, 1990).

Surface area Grouping	Rank	Reservoir	Location	Surface area (km2)	Active Storage (Mcm)
Large	1	Kenyir Dam	Kuala Brang, Trengganu	369	7400
(100 - 1000 km^2)	2	Tembeling Dam	Kuala Tahan, Pahang	250	1730
	3	Temengor Dam	Grik, Pahang	152	1270
	4	Lebir Dam	Kuala Krai, Kelantan	150	1890
	5	Neggiri Dam	Gua Musang, Kelantan	104	1570
Medium	6	Maran Barrage	Maran, Pahang	85	Run of river
(10 - 99 km^2)	7	Upper Tekai Dam	Kuala Tahan, Pahang	76	680
	8	Linggui Dam	Kota Tinggi-Kluang, Johore	53.5	740
	9	Kenering Dam	Grik, Perak	40.5	317
	10	Ulu Trengganu Dam	Kuala Brang, Trengganu	36	456
	11	Bukit Merah Reservoir	Bukit Semanggol-Taiping, Perak	34.9	56
	12	Chenderoh Dam	Kuala Kangsar, Perak	25	49
	13	Krian Barrage	Nibong Tebal, Perak	11.4	3
Small	14	Lower Tekai Dam	Kuala Tahan, Pahang	6	22
(1 - 9.99 km^2)	15	Bersia Dam	Grik, Pahang	5.7	58
	16	Pergau Dam	Jeli, Kelantan	4	53.5
Minor	17	Bertam Dam	Fort Telanok, Pahang	0.9	10
(0.01-0.99 km^2)	18	Babagon Dam	Babagon-Moyog, Sabah	0.75	13.3
	19	Sultan Abu Bakar	Ringlet, Cameron Highlands, Pahang	0.6	4.7
	20	Jor Dam	Ringlet, Cameron Highlands, Pahang	0.3	2.1
	21	Mahang Dam	Tapah, Perak	0.08	0.4



Note: Open circle represents planned impoundment; closed circle, present/completed impoundment.

Fig. 1. Major reservoirs and impoundments in Peninsular Malaysia (from Yap, 1991).

2.3.2 Tidal barrages

Tidal barrages act as drainable dams at the lower estuarine reaches (7-14 km from the river mouth) of nine lowland rivers in Peninsular Malaysia, and support substantial capture and recreational fisheries (Yap, 1991e). Krian Barrage, which is located about 14 km from the mouth of Krian River in Perak, is about 1,140 ha when fully closed in the dry season and supports capture fisheries. Upstream of the barrage, a total of 30 prawn anglers land about 105 kg/day and make daily earnings of about M$1,050 (US$1.00 = M$2.30) from the sale of freshwater prawns. Downstream of the barrage, the prawn anglers land two kg/day, earning about M$20 daily from sales of freshwater and brackishwater prawns at a farm-gate price of M$10/kg.

2.3.3 Potentials and Constraints

It is anticipated that with rapid industrialization and an increasing human population, the total reservoir area in the country will increase to about 200,000 ha by the year 2000. Tidal barrages are also expected to increase as salt intrusion problems increase and necessitate their construction in the vicinity of estuarine areas.

There is, however, a meager understanding of the potential fisheries yield of Malaysian reservoirs and a lack of infrastructure support for production and marketing. It is important that potential reservoir fisheries yields are determined and a reliable database on fish population dynamics is established (Yap, 1987) in order to have a basis for promoting investments in commercial reservoir fisheries or in intensive aquaculture in man-made lakes or reservoirs (De Silva, 1987).

2.4 Fisheries in Tin Mining Pools

Tin mining activities left numerous pits which, when filled with water, became known as disused tin mining pools. Many of these pools have outlets draining into streams and rivers although the majority cannot be drained completely.

Documentation of the early capture fisheries in Malaysian tin mining pools is lacking except for an account by Jothy (1977) on the stock-and-harvest fisheries of exotic carps in disused tin mining pools. This preliminary account reported a total of 2,332 mining pools occupying an area of 3,614 ha used for fish culture operations as of December 1975. These were mainly concentrated in the states of Perak (1,724 pools; 2,943 ha), Selangor (283 pools; 380.6 ha), and Negeri Sembilan (199 pools; 108.9 ha). In 1982, ADB (1985) reported 1,137 tin mining pools with a total surface area of about 2,182 ha only. In 1989, this number decreased to 426 covering an area of 475 ha supporting 375 fish culturists; in 1989, the figures recorded were 431 pools with a total area of about 630 ha and supporting 327 fish culturists (Table 3).

Table 3
Numbers and areas of tin mining pools supporting culture-based fisheries in Malaysia in 1988 and 1989 (from Fisheries Statistics of Malaysia, 1988 and 1989)

State	1988			1989		
	Number	Area (ha)	Number of culturists	Number	Area (ha)	Number of culturists
Selangor	242	234.79	218	230	304.78	155
Perak	134	210.61	110	149	257.48	126
Negeri Sembilan	40	15.94	40	31	43.9	28
Kedah	4	4.84	2	8	9.68	6
Kelantan	2	3.50	2	0	0	0
Pahang	2	3.50	1	1	2	1
Perlis	1	1.22	1	0	0	0
Johore	1	0.81	1	12	11.89	11
Total	426	475.21	375	431	629.73	327

The present figures suggest either errors in the earliest estimates or an underestimate in the recent figures or a real reduction in number and acreage. There is a possibility that some shallow and drainable pools have been reclaimed or converted into other uses like retention ponds for flood water or sedimentation lagoons to mitigate risks of flooding and siltation of waterways.

In the East Malaysian states of Sarawak and Sabah, the tin mining pools are not used for fisheries. In Peninsular Malaysia, the tin mining pools are managed by farmers by the stock-and-harvest technique and produce bighead carp (*Aristichthys nobilis* Richardson), grass carp (*Ctenopharyngodon idella Val.*), common carp (*Cyprinus carpio* Linnaeus), Indonesian carp (*Puntius gonionotus* Blk), and giant gourami (*Osphronemus goramy* Lacepede). Under this mixed-species culture, fish production ranges from 303.03 kg/ha (involving only Indonesian carp) to 1,795.65 kg/ha (involving a combination of bighead carp, grass carp, common carp, and Indonesian carp).

In the mid-1980s, a new direction emerged in the utilization of these marginal waterbodies for capture and culture-based fisheries with the introduction of the fast-growing Nile tilapia (*Oreochromis niloticus* Linnaeus) and red tilapia (*O. niloticus* x *O. mossambicus* hybrids) into Malaysia. Since then, there has been renewed interest in the utilization of tin mining pools for fish production.

The commercial production of tilapia in disused/undrainable tin mining pools was first reported in Bidor, Perak (Yap, 1992). A total area of 20.2 ha of tin mining pools has been modified and used for tilapia capture fisheries; a production of about 3.56 mt/ha/yr has been reported.

It is predicted that intensification of tilapia capture and culture-based fisheries will be the trend in the near future because of the success reported and the higher yields that can be achieved with minimal investment costs. However, the increased tilapia production resulting from this new enthusiasm is likely to have impacts on marketing systems and on prices.

2.5 Fisheries in Ricefields

Since the earlier documented reports in the 1970s (Tan *et al.*, 1973) and the 1980s (Meier *et al.*, 1983), fish production from ricefields remains an important source of protein and income for rice farmers (Yap and Ong, 1990; Ali, 1990). Two major areas for rice irrigation schemes in Malaysia are well-known for their high fish yields. These are the Krian ricefields (23,100 ha) in Perak State and Sekincan-Tanjung Karang ricefields (5,000 ha) in Selangor State.

Ricefield fisheries involve only minimal management inputs and do not even need to be stocked since wild fishes from swamps, rivers, and irrigation canals enter the flooded ricefields. The fish are allowed to grow, are trapped, and harvested at the end of the rice growing season. Supplementary feeding is not practised since the fishes depend on the naturally occurring food and the productivity of the fertilized ricefields. To enable the fishes to take shelter during low water due to rice harvesting activities and high water temperature, a sump pond, shaded by trees, is provided in the lowest portion of the ricefield. The sump pond is also used as fish harvesting basin. At the end of the growing season, the fish are harvested manually by pumping the sump ponds dry.

2.5.1 Fish Species and Yields

The species that are able to tolerate the extreme environmental conditions of ricefields, especially those practising double cropping, are mostly hardy and air-breathing species such as snakeskin gouramy (*Trichogaster pectoralis* Regan), three-spot gouramy (*Trichogaster trichopterus* Pallas), catfish (*Clarias batrachus* Linnaeus), snakehead (*Ophicephalus striatus* Bloch), climbing perch (*Anabas testudineus* Bloch), *Notopterus notopterus* Pallas, and *Aplocheilus panchax* Hamilton. The economically important species dominant in the harvest of two major irrigation schemes are snakeskin gouramy (a herbivore), catfish (an omnivore-carnivore), and snakehead (a carnivore).

In the North Krian Irrigation Scheme, seasonal fish yields vary from 88.3-174.6 kg/ha (see Table 1) with the maximum yield of 174.6 kg/ha believed to be probably near the maximum for this type of rice-fish farming (Ali, 1990).

The economically important species are marketed based on the following minimum sizes set by middlemen: snakeskin gouramy, >14 cm; catfish, >20 cm; and snakehead, >25 cm. Marketable species are sold to middlemen based on current market prices as follows: snakeskin gouramy, M$4/kg; catfish, M$4-6/kg; and snakehead, M$10-15/kg. These species are exported to Thailand and Singapore; they also support subsistence fisheries as the farmers living along the waterways (ricefields, sump ponds, irrigation canals, and associated rivers) harvest as much as they need for subsistence and household consumption. For instance, fish consumption is 54 and 205 g/day in the ricefields and canals, respectively, of Tanjung Piandang, Krian (Yap and Ong, 1990; Mier *et al.*, 1983).

2.5.2 Future Potentials

In view of the excessive pesticide contamination of ricefield fishes through residual adsorption into suspended detritus/sediment and bioaccumulation, there is a potential hazard of the pesticide bioaccumulating at the end of the food chain in humans (Yap and Ong, 1990). In view of the above, it is recommended that fishery products, particularly those from the ricefields from the Krian Rice Irrigation Scheme, be classified as unsuitable for human consumption.

Alternatively, it is desirable to implement resource allocation and utilization of rice plots for separate rice production and fish production in ricefields (MOA, 1982). If rice production in the Krian District is given greater importance than fish production in the ricefields, the agricultural authorities can continue to advocate the use of appropriate fertilizers and pesticides in addition to double-cropping and drainage practices aimed at increasing rice production. If this happens, the negative effects and impacts brought about by pesticides on the ricefield fishes should be disregarded, and the fish should be considered suitable only as potential fertilizers and not used as foodfish for human consumption.

3. INLAND FISHERIES MANAGEMENT

Inland capture fisheries represent the least technology-intensive approach towards increasing the production of fish protein from Malaysian inland waterbodies. These aquatic resources are beginning to receive attention for conservation and resource allocation/partitioning. River systems are managed for fisheries at two levels. First, they can be managed by direct management techniques aimed at controlling the types and amounts of fish being caught, e.g., stock-and-harvest approach as in the stocking of fry of carps, riverine catfish, and freshwater prawns (Department of Fisheries, Malaysia, 1989). They can also be managed at the river basin level using water quality and river classification as basis for the protection of aquatic life and fisheries (DOF, Malaysia, 1989). The requirement on environmental impact assessment for the conservation and retention of sizable waterfilled depressions in swamp reclamation schemes, is an important tool in this regard.

3.1 Fish Fry Stocking

Overall, fisheries stock management strategies are often based on unscientific reasoning or on trial-and-error. As a case in point, fish fry stocking programs have evolved through trial and error and have been dependent on the availability of fish fry, with little or no scientific research efforts to provide guidance or insight into the processes critical to the establishment of populations of the stocked fish. Reservoir fisheries in Malaysia is therefore not as developed as in other countries like China where the stock-and-harvest fisheries in reservoirs has reached a high state of development (Li, 1988).

Nevertheless, freshwater fish fingerlings have been produced in government hatcheries for release into public waterbodies (i.e., reservoirs, river segments, and tin mining pools). In 1988, a total of 4,484,673 fingerlings representing 69 per cent of the 6,488,789 fingerlings produced at four inland fish hatchery stations (Bukit Tinggi and Kong Kong, Johore; Jitra, Kedah; and Enggor, Perak) was released with the aim of stabilizing and enhancing the fish stocks which support the subsistence capture fisheries and the rural economy. The stocked species consisted of several freshwater fish species, namely: bighead carp, *Aristichthys nobilis* (1,862,205 fry or 41.52 percent of total); Indonesian carp, *Puntius gonionotus* (1,793,403 fry or 39.99 percent of total); common carp, *Cyprinus carpio* (576,750 fry or 12.86 per cent of total); red tilapia hybrids of *Oreochromis niloticus* x *O. mossambicus* (108,205 fry or 2.41 per cent of total); Nile tilapia, *Oreochromis niloticus* (103,505 fry or 2.31 per cent of total); and snakeskin gouramy, *Trichogaster pectoralis* (40,605 fry or 0.91 per cent of total).

In terms of sites where stocking has been carried out, only a few can be cited. For example, in order to stabilize catches of freshwater fish/prawn at Krian River downstream and at the Krian barrage, stocking of fry is practised by the Department of Fisheries, Krian District, at two strategic points at the vicinity of Krian barrage (Yap, 1991d). First, at Alor Pongsu canal, Briah swamp, 60,000 fry of Indonesian carp *Puntius gonionotus* were stocked in 1981-1987 and 100,000 fry of freshwater Malaysian giant prawn *Macrobrachium rosenbergii* were stocked in 1988 (Yap and Ong, 1990). Subsequently, the following species were stocked in 1989-1990: 5,770 snakeskin gouramy fingerlings; 2,000 red tilapia; 33,000 Indonesian carp; and 60,000 fry of freshwater prawn (Yap,1991c). Secondly, at the tributary Samagagah River, a total of 95,000 fry of Indonesian carp was stocked in 1981-1985.

The Bukit Merah reservoir was also stocked by the Department of Fisheries from 1962-1973 with 440,050 fingerlings of Indonesian carp, *Puntius gonionotus* (Yap, 1982). Subsequent to this initial stocking, freshwater prawns and six fish species were stocked between 1978 and 1990. Some 783,890 fingerlings were released consisting of Indonesian carp (411,560 fingerlings), giant gouramy (54,000 fingerlings), kissing gouramy (13,500 fingerlings), giant gouramy (2,500 fingerlings), common carp (158,330 fingerlings), bighead carp (44,000 fingerlings), and freshwater prawn (100,000 fry). The associated waterways like the diversion canal and the spillway outlet of the dam were similarly stocked with *Puntius gonionotus* (165,000 fingerlings) and *Trichogaster pectoralis* (12,500 fingerlings).

However, the impacts of management tools on the enhancement of capture fisheries stocks cannot be adequately assessed or determined due to the lack of documentation other than anecdotes or insights gained from the counsel of traditional fisherfolk and fish traders at the reservoir site over the years. The extreme difficulty of differentiating between stocked fingerlings and those derived from self-reproduction of mature fish stocked earlier, further complicates the problem.

3.2 Water Quality Standards and River Classification for Fisheries

Water quality standards have been adopted to guide in the classification of rivers and the conservation and preservation of aquatic life, including sensitive commercially important fishes, and the protection of water users (Yap, 1988).

Based on accepted criteria, waterbodies in Malaysia are classified as follows:

(i) Class I includes waterbodies of excellent quality which meet the most stringent requirement for aquatic life and fisheries protection in environmentally sensitive waters (e.g., natural park areas, fountainheads, highlands, and uninhabited areas);

(ii) Class II includes waterbodies of good quality, based on criteria for protection of sensitive aquatic species;

(iii) Class III includes waters which can sustain common and moderately tolerant aquatic species of economic value;

(iv) Class IV includes waters with marginal water quality which can sustain only hardy fish species; and

(v) Class V includes waterbodies which have no beneficial uses.

3.3 Conservation of Swamp Habitats

Swamp reserves of considerable acreage are retained to serve as natural genetic pools of swamp-dwelling fishes and other biota. In the Krian Swamp Drainage Scheme, a total of 400 ha of swamps has been left intact to act as a water retention pond for flash floods. This area has potentials for integrated fisheries/aquaculture development although the critical area/size of the swamp reserve necessary to maintain biological diversity still needs to be assessed (Yap, 1991c; Yap and Ong, 1990).

3.4 Water Resource Allocation

To provide a secondary source of income and nutrition to the rice farmers, it is recommended that rice-fish culture be carried out in flowing waters like irrigation canals and specially constructed ponds in idle plots that have not been affected by the possible indiscriminate use of organochlorine pesticides (MOA, 1982). Such proposed partitioning of the resource between rice cultivation and fish production is anticipated to produce changes in fish yields. It is necessary, however, to conduct research and training to provide the scientific base for the development of this fishery and the actual implementation of resource allocation and the utilization of ricefields for separate rice production and fish production.

4. PROFILE OF A CAPTURE FISHERY COMMUNITY

The following account is based mainly on the findings of a 1978-1982 and a 1990 socio-economic sample survey of fishing communities at Bukit Merah Reservoir (Yap, 1982, 1991e) as compared to other inland capture fishery households along rivers in Perak State (like Kurau River downstream of Bukit Merah Dam, Krian River, and Terus River, a tributary of Perak River). The data were collected by trained enumerators through personal interviews with household heads and fishermen using a structured questionnaire at fish landing sites (Yap, 1982).

4.1 The Fishing Community

Fishing on the wild stocks of Bukit Merah Reservoir is a local river basin phenomenon. Bukit Merah residents account for 87 per cent of the total fishing population, with the other 13 per cent being non-residents from Krian River basin who are associated with the fishing industry either as traders or fish processors or casual anglers. About 30 outsiders or visitors per month engage in sport fishing at the spillway during high water. However, angling or recreational fishing census was neither attempted nor possible in the scattered semi-permanent water bodies.

There are 150 fishing households in Bukit Merah and its vicinity, with an average of four adults, mainly men, actually involved in fishing. Thus, there are about 600 fishermen in the area. About 50 per cent of the fishermen-families are full-time fishermen, while the remaining 50 per cent are part-time fishermen who are also engaged in the cultivation of crops such as rubber (20 per cent) and rice (30 per cent).

Based on their length of years of employment as fishermen, the 600 fishermen can be classified into 11 groups ranging from recent fishermen (1-5 years fishing) to long-time fishermen (>51 years fishing) (Table 4).

Table 4
Length of employment (years) as fishermen, Bukit Merah Reservoir
(from Yap, 1982 and 1991)

Length of Employment (yrs)	Percentage of Respondents	
	1978 - 1980	1990
1 - 5	18	5
6 - 10	16	3
11 - 15	14	2
16 - 20	15	0
21 - 25	6	6
26 - 30	10	7
31 - 35	10	6
36 - 40	1	6
41 - 45	2	14
46 - 50	4	23
>51	4	28
Number of fishermen responding	600	358

In an earlier survey (Yap, 1982), the age composition of the fishermen showed either an increase in the number of new fishermen and/or a departure of fishermen after a few years of fishing. The 1991 survey showed an increase in the percentage of old fishermen (>40 years in fishing) from 10 per cent in 1982 to 65 per cent in 1990 while the young fishermen (<20 fishing years) constitute an insignificant percentage (10 per cent of the respondents). This suggests an immigration of the young out of the fishing village. A separate socio-economic survey (LKWK, 1986) on the Krian swamps at the vicinity of the Bukit Merah Reservoir showed that 67 per cent of the rural population belonging to the 15-30 year old age group migrated out.

4.3 Usage and Distribution of Fishery Products

Table 5 shows the various uses the full-time fishermen have for their catch. Most fishermen (83.34 per cent) report that their catch is traded and consumed, with priority being given to trading and with the unsold surplus consumed at home. A few fishermen (10 per cent) use their catch only for home consumption, and a negligible number disposes of their catch in other ways.

Table 5
Utilization of catch of full-time fishermen at the Bukit Merah Reservoir

Use	Number of Fishermen	Percentage of Total Reporting
Home consumption	30	10.00
Sale	140	46.67
Consumption and sale	110	36.67
Feed to pets	5	1.66
Aquarium	15	5.00
Release	-	-
Total responding	300	100

The inland waterbodies and aquatic resources in Malaysia support diverse freshwater fisheries, sustain subsistence and auto-consumption fisheries, tropical aquarium fisheries, and recreational/sport fisheries.

4.3.1 Subsistence and Auto-Consumption Fisheries

Freshwater fish for food is by far the most important use in areas far removed from the coast and where freshwater fish therefore constitute the only significant source of animal protein in the daily diet of the population.

Transaction of harvested products between fishermen and fish traders is a daily affair at the reservoir site. The two peak business hours are 0600-0900 and 1700-1830 hrs. The catch is then transported and distributed to nearby towns by motorcycle and car. The fish catch landed at off-hours, second-grade fish and/or surplus catch, especially during the breeding season, are sold to three local fish dealers either for sale at much lower prices or for processing into dried fish. The dried fish is then transported to nearby towns.

4.3.2 Aquarium or Tropical Hobby Fisheries

The cyprinids are favored for use as ornamental and hobby fish due to their physical appearance (small sizes and attractive colors), their behavior, and biological features. The colorful and diversified cyprinids like *Rasbora trilineata* Steindachner, *Rasbora elegans* Volz, and *Rasbora heteromorpha* Duncker, fighting fish (*Betta pugnax* Cantor), and the highly-priced bony-tongued fish (*Scleropages formosus* Mull. and Schl.) are popular aquarium fishes, both locally and internationally. Other species which are disposed as aquarium species are kissing gouramy (*Helostoma temmincki* C & V.), giant gouramy (*Osphronemus goramy* Lacepede and *Acanthopsis choirorhynchus* Blk Cobitidae). The former two anabantids are also disposed as food fish. Some expensive aquarium fishes are exported to neighboring countries like Singapore and Thailand. In Pahang Tenggara, at least 20 aquarium fish are exported, bringing an income worth about M$2 million (Furtado and Mori, 1982). To this amount, the Pahang River and freshwater swamp forest (Tasek Bera) contribute a significant proportion. The rhithronic headwaters of some large, unregulated rivers provide clean-water habitats for the existence of unique assemblages of aquarium and hobby fishes of the tropics (e.g., Linggui River) (Yap, 1990c).

The capture of live fish for aquarium use is popular among five per cent of the 600 respondents at Bukit Merah Reservoir. Intermittently, there are live-fish transactions to urban areas such for the bony-tongued fish (*Scleropages formosus*), Indonesian carp (*Puntius gonionotus*), and marble goby (*Oxyeleotris marmorata* Blk). The 30 adults engaged in trading of live fish caught the juveniles of the fish (<five cm) by hand nets and scoops and packed the fish in aerated plastic bags for transport.

None of the fish is released back into the reservoir. The non-consumable or degraded-quality fish are at least used as pet food.

4.3.3 Recreational/Sport Fisheries

Recreational fishing is becoming popular in urbanized areas. Exotic fish species like Chinese carps and tilapia are stocked to supplement the already depleted fish stocks of the potamonic lower reaches and open waters.

5. RESEARCH DIRECTIONS FOR MALAYSIAN INLAND CAPTURE FISHERIES

The inland fisheries of Malaysia is characterized by the lack of sufficient knowledge on the sustainable yields for most waterbodies. The present poor state-of-the-art in inland capture fisheries could be attributed to the low investment in scientific research and in management inputs, resulting in a very depressed state of inland capture fisheries development in Malaysia as a whole.

The factors that have constrained the optimum utilization of inland waterbodies for capture fisheries include the following: (i) difficulty of estimating the carrying capacity of a waterbody; (ii) poor data on fishing effort and efficiency of fishing gear types; (iii) lack of proper records on the suitability of fish species for stocking and on the potential returns from such stocking; (iv) poor knowledge on the impact and effectiveness of the ongoing fisheries management techniques and strategies under controlled conditions; and (v) difficulty of inspiring and involving local fishing communities in the implementation and enforcement of management measures to ensure the sustainability of the fisheries after its establishment.

Future research could be undertaken in the following areas:

(i) Verification of variabilities in fish yields of Sarawak and Sabah rivers and streams with focus on the life histories of the dominant species and population dynamics of the main species supporting the capture fisheries;

(ii) Approximation of potential fish yields for other undocumented reservoirs to promote investments in Malaysian reservoir fisheries and to provide a base for planning and decision-making on investment inputs;

(iii) Conservation of indigenous fish communities in open waters along lines taken by the EEC-DOF program in Malaysia;

(iv) Comprehensive tagging program to mark-and-recapture the stocked fish, thus facilitating estimates on population density, movement range, and the impact of stocking efforts, particularly to overcome the extreme difficulty of differentiating between stocked fingerlings and those derived from self-reproduction of matured exotic species stocked earlier;

(v) Quantification of the gains and losses in riverine fisheries resources resulting from swamp drainage and conversion to other land uses like agriculture and aquaculture; and

(vi) Feasibility of adopting and applying the concept of "Area Fisheries Management Schemes (AFMS)" to cost-effectively upgrade the status of Malaysian inland capture fisheries from its still depressed condition to one that is more organized and scientifically sound (Willmann *et al.*, 1989). The concept of AFMS aims at testing and demonstrating the value of fisheries management measures under controlled conditions. There are two main reasons for recommending such an approach. Firstly, by restricting the geographic area, it is possible to reduce the costs of implementing and enforcing management measures as administrative and research requirements are reduced in size. Secondly, it is easier to involve the fishing communities from a local area in the process of management. The latter can provide an incentive for fishermen to support the proposed measures and take active part in their enforcement.

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REVIEW OF THE INLAND FISHERIES OF PAKISTAN

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1. INTRODUCTION

The fisheries sector contributes only 0.8 per cent to total national gross domestic product (GDP) and about 3.7 per cent to agricultural GDP. Nonetheless, the fisheries is an important sector in view of the highly valued protein contained in the average annual production of 440,000 mt of fish and the employment it provides to the country's 350,000 people engaged in fishing and related activities.

The major sources of fish in Pakistan are the Exclusive Economic Zone (EEZ), which extends offshore up to 370 km, and 8.5 million ha of inland waters which produce about 20 per cent of the country's total fish production. Only about 26 per cent of the total production is consumed locally; the rest is either exported or processed as fish meal. Per capita fish consumption is very low at 1.6 kg/yr and is likely to remain constant in the next 15 years due to the country's limited potential for increased production and the high population growth rate. The Government of Pakistan recognizes these and has put fisheries development high in its order of priorities.

There are about 152 freshwater fish species found in Pakistan belonging to the following families: Clupeidae, Notopteridae, Salmonidae, Cyprinidae (of which there are 69 species), Cobitidae, Bagridae, Sisoridae, Schilbeidae, Siluridae, Amblycipitidae, Badidae, Cichlidae, Mugilidae, Gobiidae, Anabantidae, Mastacembelidae, and Synbranchidae (see Annex A for full list).

2. RESOURCES

2.1 Areal Extent and Development Potential

Pakistan possesses extensive inland water areas comprising the Indus River and its tributaries Jhelum, Chenab, Ravi, Sutlej; a vast canal irrigation system; natural lakes and storage reservoirs, village ponds, and water-logged areas of varying sizes. The Indus River flows from North West Frontier Province (NWFP) through Punjab Province where it joins its tributaries, flows through the province Sind, and forms the Indus delta before falling into the Arabian Sea. The Indus basin system contains several reservoirs, barrages, 44 extensive canals, and irrigates 16 million ha of land through 89,000 water

courses and irrigation canals. Due to the lack of drainage canals, several thousands of sq km of water-logged areas have evolved which offer varied potential for aquaculture and inland fisheries development. The extent of these water resources in Punjab, NWFP, and Sind is summarized in Table 1 and a map showing the major rivers and reservoirs is presented in Figure 1.

In Baluchistan, there are not many opportunities due to the arid climate and scant water resources. However, there may be a limited possibility for development of fish ponds in Dera Murad along the Sind border near Jacobabad.

The state of Azad Jammu and Kashmir (AJK) with an area of 13,297 sq km, is landlocked but endowed with vast water resources in the form of rivers, streams, nullahs, springs, brooks, lakes, and man-made reservoirs. Neelum river runs for about 150 km in AJK and forms a confluence with the river Jhelum at Dommel (Muzaffarabad). The tributaries Jagran, Leepa, and Surgeon join this river. The temperature in Neelum river ranges from 0-12°C depending on the season and the locality. The principal fishes in this river are all coldwater species, mainly rainbow, brown, and snow trout.

Jhelum river originates from Vular lake (India), flows eastward through Chinari, Chukoti, Hatian, and Garhi Dopatta, and runs 300 km before joining Neelum at Muzaffarabad. Water temperature varies from 8-30°C depending upon the season and the locality. It supports fish fauna comprising mainly of carps (*Cyprinus carpio, Cirrhinus mrigala, Catla catla*). The river offers breeding places for some Mangla reservoir fishes.

The river Poonch runs 85 km before falling into Mangla reservoir. Its temperature ranges from 12-30°C and sustains populations of *mahaseer* (*Tor spp.*), *mullee* (*Wallago attu*), *mori* (*Cirrhinus mrigala*), *gulfam* (*Cyprinus carpio*), and *thaila* (*Catla catla*).

In addition to these rivers, reservoirs like Baghsar (10 ha) and Subri (20 ha) and lakes have some fishery potential.

2.2 Federal Agencies In Charge of Water Resource Management

2.2.1 WAPDA

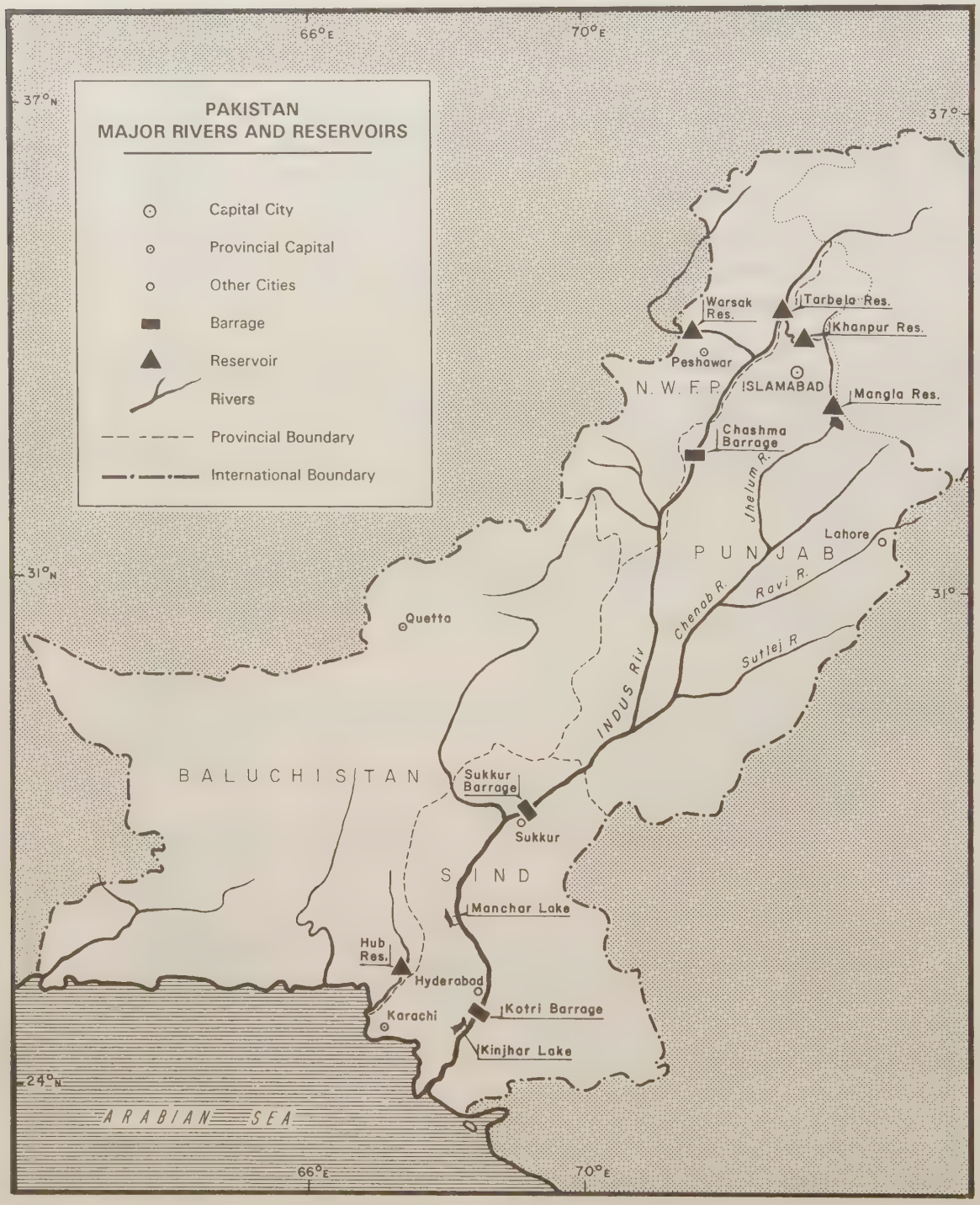
The Water and Power Development Authority (WAPDA) of Pakistan is a semi-autonomous federal agency developed in 1958 as Pakistan's first statutory entity to manage and develop its water and power resources. It is the executing agency for developmental projects for major water resources, operating under the Federal Ministry of Water and Power.

Under the Indus Basin Project Treaty, dams have been constructed across rivers for water storage in order to generate hydropower and to supply water for irrigation canals. Consequently, reservoirs have emerged which offer huge potential for fish production. This potential varies, however, with the geographical, meteorological, and

Table 1
Water resources in the three provinces of Pakistan
(Punjab, NWFP, and Sind)

Water Resources	Area (ha)
A. Punjab	
1. Rivers and major tributaries	
- Maximum during summer	2,940,000
- Maximum during winter	713,000
2. Major perennial canals	22,600
3. Reservoirs attached to barrages	40,840
4. Dams	24,960
5. Natural lakes	6,700
6. Water-logged areas	9,200
7. Saline/waste lands	20,800
8. Abandoned irrigation canals	1,440
9. Fish farms	10,000
Sub-total	3,789,540
B. North West Frontier Province (NWFP)	
1. Rivers and Tributaries	2,400
2. Reservoirs	26,800
3. Natural lakes	2,080
4. Water-logged areas	1,600
Sub-total	32,880
C. Sind Province	
1. Rivers (Indus and Hub)	160,000
2. Canals and drains	32,000
3. Abandoned canals, ponds	98,000
4. Water-logged areas	3,000,000
5. Depressions along road and river flood areas	1,000,000
6. Indus delta	385,000
7. Fish culture ponds	3,000
Sub-total	4,678,000
Total	8,500,420

Fig. 1. Map of Pakistan showing its major rivers and reservoirs.



ecological conditions of the reservoirs (Table 2). The major commercial species found in the reservoirs are rohu (*Labeo rohita*), mori, thaila, and gulfam. In reservoirs located in the high-altitude mountain areas, mahaseer is very common; silver carp and grass carp are also cultivated.

Table 2
Major reservoirs under WAPDA supervision

Reservoir	Type	Water area (ha)		Maxim Depth (m)	Drawdown (m)	Water Retention
		Wet season	Dry season			
Chashma	shallow	36000	9000	8	1.5	1 :10
Hub	shallow	9894	1820	46	19	1 : 1
Khanpur	shallow, wide	1806	215	51	24	1 : 3
Mangla	deep	25900	8700	91	50	1 : 3.7
Tarbela	deep, narrow, V-shaped	25600	8800	137	77	1 : 5.6
Warsak	V-shaped, in deep valley	1036	N.A.	48	8	1 : 100

Source: DOF, WAPDA.

2.2.2 Capital Development Authority (CDA)

The Capital Development Authority administers the federal area of Islamabad where Simly Dam has been constructed in the south for water storage to supply Islamabad. The reservoir, with a water area of 1,090 ha, has been stocked with common carp and major carps and has natural populations of mahaseer. Simly Dam was stocked to promote sports fishing in the area.

2.2.3 Federal Ministry of Northern Affairs

In the northern areas (Gilgit and Skardu), administered by the Federal Ministry of Northern Affairs, numerous rivers, streams, and springs offer some potential for development mostly for trout culture.

3. PRODUCTION TRENDS

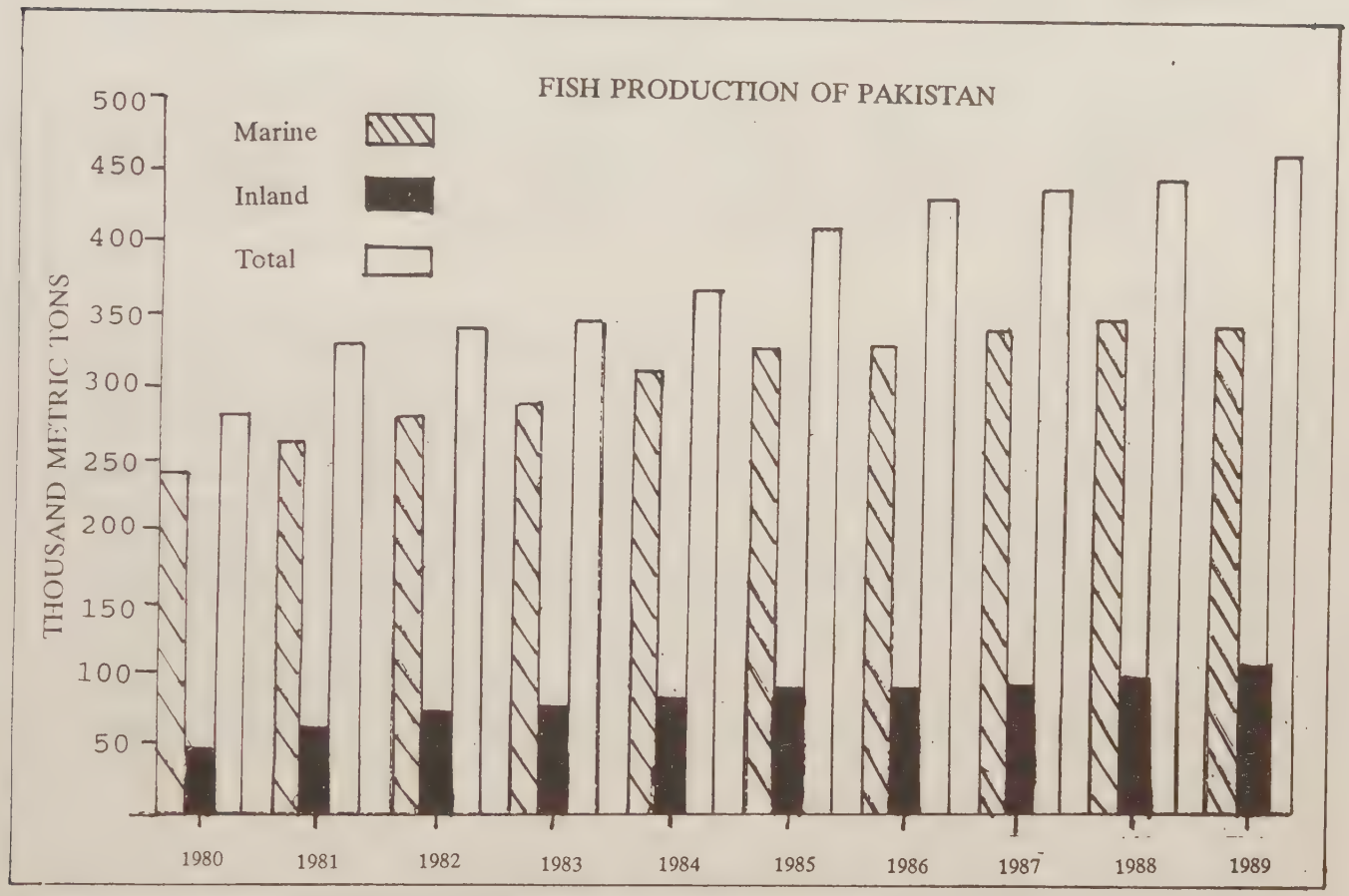
The inland fisheries production from the country's open waters and reservoirs has shown considerable growth over the period 1981-1989, with the total yield of 105,009 mt in 1989 almost double the 56,310 mt produced in 1981 (Table 3; Fig. 2). The province of Sind has been consistently the top producer, contributing roughly 50 per cent to the total production from inland waters over the 1981-1989 period.

Of the total production, the bulk comes from capture fisheries and a small portion is contributed by aquaculture. For example, of the approximately 84,000 mt in 1986, some 78,000 mt came from fish capture and the rest from aquaculture. With the encouraging growth in aquaculture in the past decade, however, it is expected that the yields from this subsector, particularly in brackishwaters, are likely to increase in the coming years.

Table 3
Production from inland fisheries (mt) in Pakistan

Area	1981	1982	1983	1984	1985	1986	1987	1988	1989
Punjab	17,090	18,814	19,925	24,534	26,806	31,775	36,432	41,230	45,239
Sind	36,751	57,289	37,405	44,619	44,577	50,840	53,635	54,000	57,500
NWFP	929	850	574	782	795	575	806	496	910
Baluchistan	–	–	–	–	–	–	–	–	–
Northern Areas	8	8	40	35	33	39	65	75	85
WAPDA reservoirs									
Mangla	1,421	1,969	1,725	–	666	132	149	475	486
Chashma	123	449	690	636	211	588	485	585	708
Tarbela	67	46	–	–	–	44	58	60	79
Hub	–	–	–	–	–	–	–	23	–
Khanpur	–	–	–	–	–	–	–	1	2
Total	56,389	79,425	60,359	70,606	73,088	83,993	91,630	96,945	105,009

Fig. 2. Contribution of inland fisheries to the total fish production of Pakistan.



Source: Marine Fisheries Department, G O P, Karachi, 1990

Carp hatcheries have also been set up at Ratta Kulachi (D.I.Khan), Tanda Dam (Kohat), Charbanda (Mardan), Ichrian (Mansehra). These hatcheries have a total production capacity of two million fry which are either grown to market size in private carp farms or stocked in open waters in the Province. At present, there are 28 such farms covering an area of 16 ha, whose success has not been determined yet.

DOF has been stocking public waters with fingerlings of trout and carp. Since 1981/82, over one million fingerlings have been released annually (Table 5).

Table 5
Fish fingerlings stocked in public waters

	1981/82	1982/83	1983/84	1984/85	1985/86
Trout	372,000	310,000	265,700	440,000	414,000
Carp	840,000	844,000	980,000	785,000	1,084,000
Total	1,212,000	1,154,000	1,245,700	1,225,000	1,498,000

3.2 Punjab Province

The geo-meteorological and hydrobiological conditions of the water bodies in Punjab favor carp culture and mixed culture. The major carp species grown in the Province are: rohu (*Labeo rohita*), mori (*Cirrhinus mrigal*), and thaila (*Catla catla*). The other species found in Punjab include the following: (i) Chinese carps: common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), and grass carp (*Ctenopharyngodon idella*); (ii) tilapia (*Oreochromis* spp.); and the carnivorous (predatory) species including mahaseer (*Tor putitora*), khagga (*Rita rita*), mullee (*Wallago attu*), singharee (*Mystus aor*), and soul (*Channa marilius*).

The bulk of fish production in the Province is derived from capture fisheries from rivers, canals, reservoirs, lakes, and ponds, which have been stocked with millions of fish fingerlings (Table 6). The catches/yields from these sources increased from 13,100 mt in 1980/81 to 21,300 mt in 1985/86.

Table 6
Fish production from inland waters

Year	Fish seed produced (millions)	Fish seed stocked (millions)			Fish production (mt)
		Total	Public waters	Private sector	
1980/81	5.8	5.15	-	-	13,100
1981/82	6.5	6.47	5.786	0.684	15,200
1982/83	6.6	8.00	7.192	0.808	16,900
1983/84	8.9	10.00	8.914	1.098	17,870
1984/85	10.9	13.00	11.459	1.568	19,400
1985/86	16.5	18.11	15.817	0.293	21,300

Source: DOF, Punjab.

The trends in production from inland fisheries and aquaculture vary from one province to another depending on geo-meteorological and ecological conditions, as discussed below.

3.1 North West Frontier Province (NWFP)

The North West Frontier Province produces about 768 mt of fish per year excluding the production from Tarbela and Khanpur reservoirs and the Northern Areas. This Province is better known for sport fishing for trout or mahaseer. Its climatic and hydrobiological conditions favor the production of coldwater fish like trout.

The transition from cold to warmwater system occurs as the river moves from north to south. When the Indus River and its tributaries - Swat River, Kabul River, and Haro River - emerge from the hills, warmwater fish culture begins. The transitional zone produces mixed culture like *Schizothorax* spp., mahaseer, and catfish. Trout culture is practised in Kaghan, Swat, Dir, and Chitral valleys.

Aquaculture operations in NWFP include the intensive raceway trout farm operated by DOF in the Swat Valley, which was constructed under the ADB-financed Aquaculture Development Project. The farm is operating successfully, with an annual production of 10,000 kg of trout. The farm uses feeds formulated from locally available ingredients and sold at Rs. 9.40/kg; feed conversion rate averages 2:1, for a total feed cost of Rs. 18.80/kg of fish produced. Since feed represents about 70 per cent of production cost and the farmgate price of trout is Rs. 40/kg, the operation appears to be profitable. In view of the commercial demand for trout, private sector is setting up trout farms in Swat Valley. In support of the development of the trout fisheries, the DOF has established hatcheries at Shinu (Kaghan Valley), Madyan (Swat Valley), Kalkot (Dir Valley), Jaghoor, and Bombrit with a total production capacity of 1.15 million fry (Table 4). Another hatchery is situated in Madagalast (Chitral).

Table 4
Production of NWFP hatcheries

Hatcheries	Production Capacity (Number of fingerlings)
for trout culture	
1. Shinu (Kaglan Valley)	300,000
2. Madyan (Swat)	500,000
3. Kalkot (Dir)	100,000
4. Jaghoor (Chitral)	120,000
5. Bombrit (Chitral)	130,000
Sub-total	1,150,000
for carp culture	
1. Ratta Kulachi (D.I. Khan)	500,000
2. Tanda Dam (Kohat)	350,000
3. Charbanda (Mardan)	1,000,000
4. Ichrian (Mansehra)	150,000
Sub-total	2,000,000
Total	3,150,000

In addition, production through aquaculture has been promoted by DOF Punjab. Six hatcheries (Chenawan, Faisalabad, Multan, Lahore, Rawalpindi, and Bahawalpur) and 22 nurseries have been set up in order to produce about 16 million fish seed for stocking and fish farming in the Province (Table 7). Of the fingerlings produced, 60 per cent consists of major carps; 35 per cent, common carp; and five per cent, silver and grass carps. About 5,000 fishfarms covering a water area of 1,500 ha have been established in Punjab with a yield potential of 1,000-1,500 kg/ha/yr. Some fishfarmers have even attained exceptionally high yields of 2,500 kg/ha/yr.

Table 7
Production of fishseed in Punjab fish hatcheries (in millions)

Hatcheries	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Bahawalpur	–	–	0.1	0.1	0.3	0.7
Chenawan	2.2	2.6	2.7	2.7	3.2	3.3
Faisalabad	1.4	1.7	1.6	2.4	2.0	2.7
Lahore (Muhawan)	0.7	0.6	0.6	1.2	2.3	4.4
Multan	1.5	1.6	1.5	1.7	1.6	2.8
Rawalpindi	–	–	0.1	0.8	1.5	2.6
Total	5.8	6.5	6.6	8.9	10.9	16.5

Source: DOF, Punjab.

3.3 Sind Province

The bulk of inland capture fisheries production in Sind Province originates from rivers (Sind, Hub), canals and lakes (Kinjhar, Dakar, Manchar), ponds, and water-logged areas (Table 8). The catfishes and major carps dominate the catches (Table 9) while the most dominant and anadromous fish, palla (*Hilsa ilisha*) has declined from 70 per cent to 15 per cent due to the barrages and dams constructed across the Indus River.

Table 8
Fish production from Sind lakes (in mt)

Lake	Area (ha)		Year			
	Wet Season	Dry Season	1982	1983	1984	1985
Manchar	30,000	3,000	180	172	164	154
Kinjhar	23,000	22,000	700	710	715	730
Dakar	71,000	70,000	860	810	820	825
Total	124,000	95,000	1,740	1,692	1,699	1,709

Table 9
Percentage composition of the different fish species produced in the province of Sind

Species	Percentage
Labeo rohita	15
Catla catla	15
Cirrhinus mrigala	15
Labeo calbasu	12
Catfishes	35
Others	8
Total	100

Source: DOF, Sind.

A unique feature of the fishery in Sind is the fishing of compartments/ embarkments constructed on both sides of the rivers in front of the river Indus in front of the Sukkur Barrage. These embarkments/compartments range in size from 50-5,000 ha and after filling with water, look like fishponds in every respect. Water is let into the compartments during the peak flood periods (June and July) which coincide with the spawning period of many species especially the major carps. Large numbers of carp fry as well as adult fish enter these compartments; millions of carp fingerlings produced by DOF Sind at its hatcheries and nurseries are also stocked (Table 10). In a few months, the fish grow to market sizes. Before the water recedes in the dry season, i.e., November or December, the fish are harvested by fishermen hired by the private contractors who lease the compartments from DOF. The catches consist mostly of major carps and other species. Fish production and yields vary between compartments in the different areas (Table 11).

Table 10
Fish fry production (in '000) from Sind hatcheries

Hatchery	1983/84	1984/85	1985/86
Chilya	826	2,903	3,686.3
Sukkur	-	-	2,700.0
Khandh kot	-	-	697.8
Mando Dero	-	-	28.6
Total	826	2,903	7,112.7

Table 11
Fish production from compartments in Sukkur Division

Compartments	Area (ha)	Production (mt)					Yield (kg/ha/yr)
		1981	1982	1983	1984	1985	
Naseerabad	240	1.7	1.5	1	1	1	5
Bechanjee	120	5	5.1	5.5	6	6	46
Dalhar	320	3.6	3.5	3.8	4	4	12
Shahwani	40	3.5	3.8	4	4	5	101
Arain	240	180	181	186	188	190	770
Shahpur	240	4	4.2	4.8	5	5	19
Mazarjee	160	1.8	2	1.9	2	2	12
Abdur Takio	600	1	0.9	1	1	1	2
Doung	2,000	385	390	392	394	395	196
Ghouspur	4,200	235	239	242	248	250	58
Ghora Ghat	5,120	220	226	227	230	230	44
Total	13,280	1,041	1,057	1,069	1,083	1,089	1,265

Source: DOF, Sind.

Aquaculture in the Province involves mainly the farming of major carps in 168 fish farms covering an area of 1,684 ha (Table 12). Fishfarms are either natural depressions in water-logged areas or excavated land filled with water. Pond management is minimal and yields, even of well-constructed ponds, are low.

Table 12
Fish farms and their areas in Sind

District	Number	Average size (ha)	Area (ha)
Hyderabad	11	1.6	18
Thatta	47	3.0	140
Badin	10	3.2	32
Sanghar	2	7.0	14
Nawabshah	2	4.6	9.2
Sukkur	58	5.9	341
Jacobabad	36	31.1	1,120
Other	2	5.2	10.4
Total	168	10.0	1,684.60

Source: DOF, Sind.

Shrimp aquaculture is also practised in Sind. Of the 385,000 ha of intertidal area considered for shrimp culture, the Government has allocated 6,400 ha to the private sector to develop and operate as shrimp farms. These areas are supplied with water from numerous creeks which also serve as spawning and nursery areas for various shrimp species.

DOF started a shrimp farming pilot project in Thatta district as part of the ADB Aquaculture Project implemented with private sector participation. At present, however, there is only one private company (Lipton Pakistan Ltd.) actively engaged in shrimp farming in a small 12-ha pilot project.

3.4 Azad Jammu and Kashmir (AJK)

The fish production of AJK comes from rivers and their tributaries. Trout, carp, and catfish are caught. Commercial exploitation is limited, scattered and unorganized, and not properly recorded. Production has increased, though, from just about 1,082 kg in 1975-76 to about 3,500-3,700 kg in the 1980s (Table 13). Only 200 persons are engaged in fishing activities and 30 persons are engaged in fish handling. Licenses for sport fishing or angling are given out and recorded but the catches of anglers are not controlled due to lack of the required institutional support.

Table 13
Fish production of AJK

Year	Quantity (kg)	Year	Quantity (kg)
1975-76	1,082	1981-82	3,695
1976-77	1,749	1982-83	3,664
1977-78	1,458	1983-84	3,510
1978-79	2,597	1984-85	3,572
1979-80	3,664	1985-86	3,580
1980-81	3,733		

Source: Fisheries Section, Forestry Department, Muzzaffarabad.

Fish farming in cold waters and in warm waters is possible because of the geographical, meteorological, and ecological conditions in the area. Trout culture is being promoted in Neelum Valley and carp culture in Jhelum and Poonch Valleys.

3.5 Northern Areas

Fish production in the Northern Areas comes mostly from capture fisheries of rivers, streams, and lakes. Commercial-scale fishing is limited, with total fish production amounting to only 50 mt in 1989, including catches from angling. The major fish species produced in this area are snow trout and some catfish. The lakes and rivers are regularly stocked with trout fingerlings for which trout hatcheries and farms have been established. Ten million fingerlings are produced and stocked in lakes and rivers.

3.6 WAPDA-managed Reservoirs

The major reservoirs are managed by WAPDA which holds public auctions for the fishing rights to each waterbody. The successful bidders engage the fishermen purely on a temporary basis; in NWFP and Punjab, some of the fishermen come from other areas. From 1985-1989, the number of fishermen fishing in WAPDA-managed reservoirs increased from 1,696 to 2,315 (Table 14).

Table 14
Number of fishermen in the WAPDA-managed reservoirs

Reservoir	1985-86	1986-87	1987-88	1988-89
Chashma	951	1,100	1,100	1,474
Hub	-	-	-	193
Khanpur	-	-	-	11
Mangla	570	485	500	500
Tarbela	175	232	255	137
Total	1,696	1,817	1,855	2,315

Source: DOF, WAPDA.

Fish production in these major reservoirs has been very low and has declined by 50 per cent from 2,429 mt in 1982-1983 to 1,216 mt in 1988-1989 (Table 15).

Table 15
Fish production of major reservoirs (mt)

Reservoirs	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
Chashma	418	518	708	264	677	585	600
Hub	-	-	-	-	-	-	30
Khanpur	-	-	-	-	-	-	3
Mangla	1,750	2,694	1,902	904	-	570	520
Tarbela	161	24	-	37	67	53	63
Total	2,329	3,236	2,610	1,204	744	1,208	1,216

Source: DOF, WAPDA.

The low fish production may be attributed to a number of factors including possible overfishing, a decline in the natural populations as the breeding grounds have been submerged in deep water, the low fishing efficiency due to the poor condition of the fishing gears and boats used by the fishermen, and the lack of success of the fish stocking program.

The most common fishing gears used by fishermen are cast nets, set nets, gillnets, fyke nets, and drag nets. Fishermen still use old indigenous fishing techniques due to a lack of awareness of, and training on, modern methods/techniques. The fishing boats are mostly wooden boats with rows and sails; very few are partially mechanized and provided with winches (Table 16) although the number of motorized boats has been increasing (Fig. 3) due to efforts of the Government to promote an awareness among the fishermen on the benefits arising from the use of modern fishing craft and gear. International donor agencies like JICA, ADB, CIDA, and FAO/UNDP have also provided motor engines to fishermen at concessional rates. On a province per province basis, Punjab and Sind have the highest numbers of fishing craft in the country (Table 17).

Table 16
Number of gears used for inland fisheries

Year	Mechanized cum sail driven boats	Sail boats	Oar/Row boats	Total
1980	–	7,246	9,145	16,391
1981	2	7,887	2,065	9,952
1982	102	8,018	2,065	10,083
1983	102	7,977	2,397	10,374
1984	103	8,109	2,729	10,838
1985	213	7,890	3,100	10,990
1986	223	9,457	3,520	12,977
1987	236	10,587	3,738	14,325
1988	273	9,767	3,800	13,567
1989	305	10,245	3,860	14,105

Table 17
Distribution of fishing crafts by province

Year	Punjab	Sind	NWFP	Baluchistan	NA	Chashma	Hub	Khanpur	Mangla	Tarbela	Total
1980	5,071	10,930	250	–	–	–	–	–	–	–	16,001
1981	5,207	4,185	250	–	–	50	–	–	160	102	9,392
1982	5,323	4,185	250	–	–	150	–	–	175	102	9,508
1983	5,390	4,699	250	–	–	175	–	–	150	102	10,089
1984	5,638	5,218	250	–	4	210	–	–	150	102	10,856
1985	5,662	5,810	250	–	4	250	–	–	257	–	11,472
1986	6,506	6,470	783	–	4	325	–	–	206	32	12,976
1987	6,686	6,921	1,530	–	7	322	–	–	304	27	13,607
1988	6,805	7,000	46	–	9	303	142	6	304	30	13,805
1989	6,687	7,075	450	–	40	200	–	5	855	33	13,762

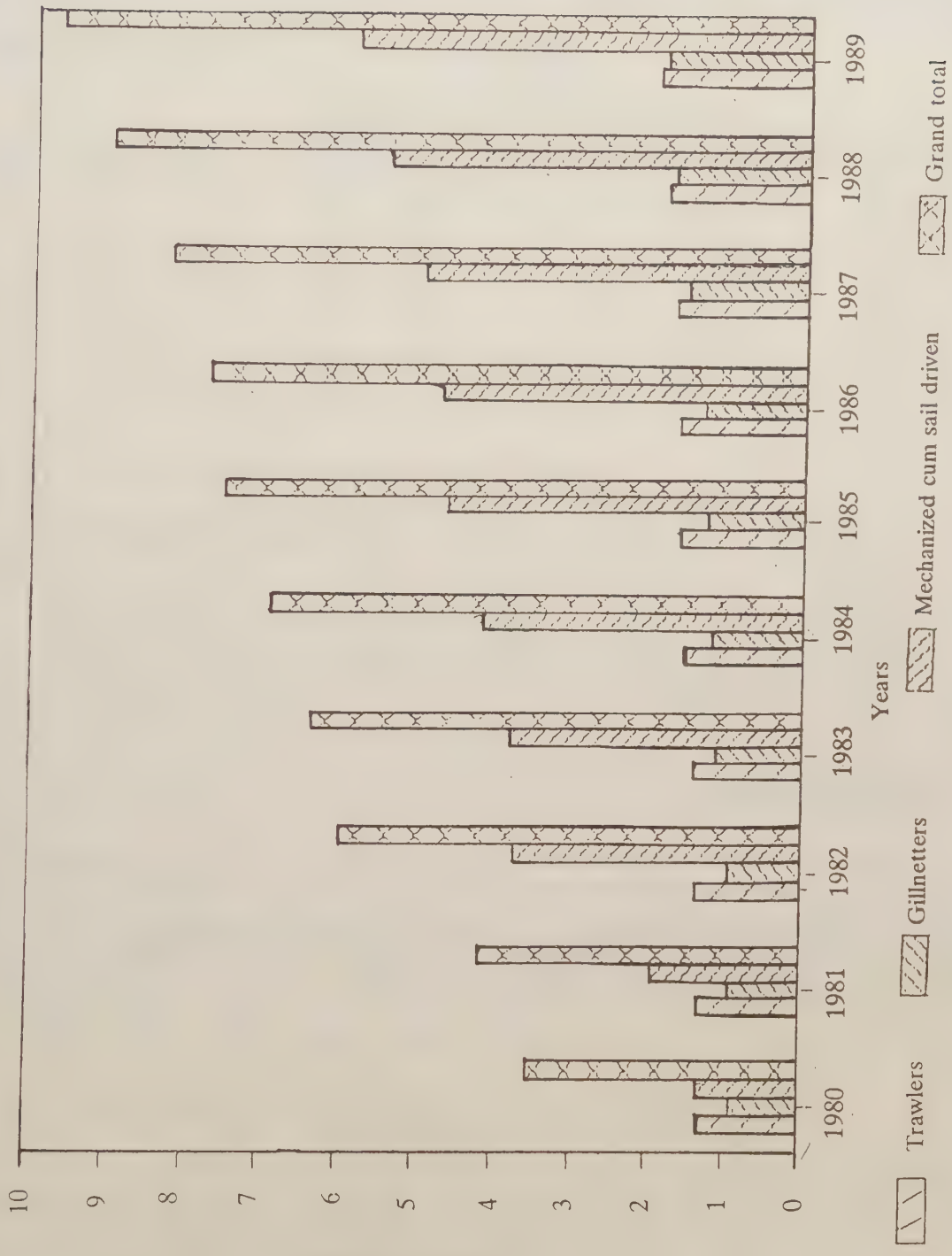


Fig. 3. Increase in mechanized fishing crafts of Pakistan, 1980-1989.

Source: Marine Fisheries Department, Karachi

The stocking program of DOF and WAPDA has also not been successful. Firstly, the quantity stocked is small and not in accordance with the seed requirement of the reservoirs due to the inadequate seed production of the WAPDA hatcheries (Tables 18 and 19). Moreover, the large populations of predatory species reduce the survival rate of the stocked fingerlings, mostly rohu, mori, thaila, and gulfam.

Table 18
Seed requirement of WAPDA reservoirs

Reservoir	Seed requirements (millions)
Chashma	5.5
Hub	1.5
Khanpur	0.15
Mangla	7.7
Tarbela	1.9

Source: Field Document No.4, FAO/TCP/6657.

Table 19
Seed production (millions) of WAPDA hatcheries

Reservoirs	1985-86	1986-87	1987-88	1988-89	1989-90
Chashma	0.200	0.150	0.200	0.250	0.215
Mangla	0.200	0.100	0.093	0.040	0.035
Tarbela	0.180	0.094	0.095	0.100	0.120
Total	0.580	0.344	0.388	0.390	0.370

Source: DOF, WAPDA.

4. THE FISHERMEN

Pakistani fishermen are either full-time, part-time, or occasional fishermen whose skills have been passed on to them from earlier generations. Over the period 1980-1989, the number of fishermen who fish in inland waters has increased from 116,935 in 1980 to 162,669 in 1989, with the full-time fishermen numbering 58,815; part-time fishermen, 52,770; and occasional fishermen, 51,084 (Table 20).

Table 20
Number of fishermen by degree of involvement in fishing

Year	Full-time	Part-time	Occasional	Total
1980	55,070	32,099	29,766	116,935
1981	50,025	36,512	31,561	118,098
1982	49,745	37,205	33,956	120,906
1983	51,676	38,734	33,965	124,375
1984	53,737	41,596	36,391	131,724
1985	53,507	42,017	35,396	130,920
1986	53,538	45,893	37,958	137,389
1987	54,565	46,296	53,393	154,254
1988	58,178	49,010	48,877	156,065
1989	58,815	52,770	51,084	162,669

By province, Punjab had the most fishermen at 128,621 in 1989 from 83,256 in 1980; Sind had the second highest number at 23,100 in 1989 (Table 21). These two provinces also have more full-time fishermen compared to the other provinces due to the emergence of the reservoirs. The numbers of part-time and occasional fishermen have also been increasing in both provinces as people with other occupations take up fishing in the reservoirs as a part-time or occasional employment.

Table 21
Distribution of fishermen per provinces

Year	Punjab	Sind	NWFP	Baluchistan	NA	Chashma	Hub	Khanpur	Mangla	Tarbela	Total
1980	83,256	26,939	5,510	-	80	-	-	-	1,150	-	116,935
1981	88,812	19,758	7,948	-	80	100	-	-	1,200	200	117,898
1982	92,236	17,830	8,300	-	80	350	-	-	1,060	50	119,856
1983	95,330	19,490	8,300	-	80	400	-	-	725	50	124,325
1984	100,162	21,159	9,130	-	400	184	-	-	725	-	131,760
1985	100,480	21,080	8,040	-	425	315	-	-	570	-	130,910
1986	108,403	21,920	5,212	-	435	954	-	-	485	65	137,409
1987	115,939	23,708	13,442	-	520	1,100	-	-	500	45	155,209
1988	122,606	22,900	8,752	-	520	1,474	49	11	500	53	156,752
1989	128,621	23,100	8,880	-	1,000	497	-	8	500	63	162,598

5. SUPPORT TO FISHERIES DEVELOPMENT

5.1 Institutional Support

Inland fisheries is the responsibility of the various provinces. The four provincial Directorates of Fisheries (DOF) are responsible for planning, licensing, leasing public waters, research, training, statistical data collection, and extension services for inland fisheries. Federal agencies like DOF, WAPDA, and the Federal Ministry of Northern Areas, also manage their waterbodies. The Fisheries Division under the Federal Ministry of FAC also plays coordinating and advisory roles on matters pertaining to national fishery policy. PARC, NIO, PCSIR, and Zoology Survey also perform related activities.

5.1.1 DOF, Sind

The Department is headed by a Director of Fisheries (DOF) who is assisted by five Deputy Directors of Fisheries (DDF) (two for Aquaculture, one for Chilya Hatchery, and one each for Sukkur and Hyderabad Divisions), 20 Assistant Directors of Fisheries (ADF), three Senior Officers, 33 officers, and 336 supporting staff.

5.1.2 DOF, Punjab

It is headed by a Directorate-General having four Directors (one for Extension, Research and Training, Hatcheries, and Aquaculture Projects), two DOFs, 70 ADFs, 218 technical staff, and 1,188 supporting staff.

5.1.3 DOF, NWFP

The Directorate of Fisheries of NWFP operates under Wild Life, Forestry Development, and is headed by a Director with 13 ADFs, 11 FTAs, and 292 other staff.

5.1.4 DOF, Baluchistan

The DOF is under the Provincial Ministry of Food, Livestock, and Fisheries. The Department is headed by a Director and several assistant directors, and has a staff strength of 176.

5.1.5 DOF, WAPDA

DOF WAPDA has 131 staff headed by a DF assisted by two DOFs, eight ADFs, and two research officers. The Directorate is financed from its own income coming from the lease of fishing rights; 50 per cent of its budget is spent on developmental activities.

5.1.6 AJK Fisheries

It is a small fisheries cell working under the Forestry, Tourism, and Wild Life Department. The Assistant-Director of Fisheries heads fisheries development under the wildlife wing assisted by two FTAs and other support staff.

5.1.7 DOF, Northern Areas

The Department has overall responsibility for fisheries development in the Northern Areas. It is headed by a DDF who is assisted by two ADFs and other support staff.

5.2 Credit Facilities

As in the marine fisheries subsector, credit facilities are available for inland fisheries and aquaculture development. All commercial banks in the country as well as the State Bank of Pakistan and the Agriculture Development Bank of Pakistan (ADBP) have been active in long- or short-term lending to fishfarmers, fishermen, fish processors, or boatbuilders for the repair of fishing vessels (Table 22). Up to 1986, the ADBP has disbursed US$1.3 million for inland fisheries. The ADBP even deputized IFMCD to provide technical assistance to fishfarmers as part of their overall effort to promote aquaculture.

Table 22
Lending to the fisheries sector (in million Rs.) by commercial banks .

Banks	Fishing Vessels		Fishing / Processing		Marketing and Export	
	Number of borrowers	Total amount	Number of borrowers	Total amount	Number of borrowers	Total amount
Habib Bank Ltd.	-	-	68	329.61	55	119.50
National Bank of Pakistan	8	3.511	6	1.04	91	4.07
United Bank Ltd.	2	1.300	30	246.511	1	0.30
Muslim Commercial Bank	-	-	-	-	2	13.50
Allied Bank of Pakistan	1	2.432	7	13.281	-	-
Total	11	7.243	111	590.442	149	137.37

Total number of borrowers: 271
Total amount loaned mt: Rs. 735.113 million

The Government has launched a scheme for interest-free production loans to small fishermen with their ponds or nets as surety. Under the export financing scheme, the Government provides credit from commercial banks on the basis of confirmed irrevocable letters of credit (LCs), with a repayment period of 180 days that can be extended up to 90 days more at a surcharge of six per cent.

5.3 Policy and Program Support

Until 1973, fisheries was a neglected sector. Due to its very low priority, development was limited and infrastructure facilities were lacking. After the visit of an FAO/UNDP Policy Mission on Fisheries, however, the Federal Government reviewed its policy and set up new priorities for fisheries development. Maximum attention was paid to marine fisheries, it being the major source of fish production; little attention was given to inland fisheries.

In the 70s, after a survey of the inland fisheries potential revealed that it could be a source of additional production, the Government reconsidered its position vis-a-vis the inland fisheries and put its development on the same level as the marine fisheries subsector. In spite of budgetary constraints, long- and short-term programs were formulated to raise fish production from inland resources by efficient management and optimum utilization. The major priority in the planning process was given to the establishment of fish hatcheries and nurseries for large-scale production, the development of necessary institutional and infrastructural facilities for production enhancement, and the promotion of aquaculture on a commercial scale. The private sector was mobilized to set up fish farms and hatcheries, and promote the allied activities to enhance fish production. Major attention was focused on the provision of basic facilities and the extension of modern techniques like induced breeding and introduction of exotic species. Moreover, manpower training and research and extension were also provided.

As a result of these efforts, the fisheries sector has been growing at an annual growth rate of 2.4 per cent, with the projected production of 403,000 mt in the last Five-Year Plan attained in 1985 (Table 23). In the current development plan, it has been projected that the 75,000 mt contributed by the inland fisheries (representing an 8.6 per cent share of total production) in 1985 will increase by 2.3 per cent per annum to reach 90,000 mt by 1992 (Table 23). This increase of 15,000 mt over the 1985 level is projected to consist of 5,000 mt from aquaculture and 10,000 mt from managed reservoirs and other inland waters. By the year 2000, it is expected that inland fisheries would reach a production of 110,000 mt, of which 91,000 mt are to come from inland capture fisheries and 19,000 mt from aquaculture.

Table 23
Actual (1985) and projected (1993 and 2000) fish production by subsector

Subsector	Production Volume (in '000 mt)			Projected Annual Growth Rate (%)	
	Actual	Projected			
	1985	1993	2000	1985–1993	1993–2000
Marine fisheries	333	403	403	2.4	–
Inland fisheries					
Capture	71	81	91	1.7	1.5
Aquaculture	4	9	19	7.9	7.5
Total	408	493	513		

For the period 1987-2000, the country's fisheries development objectives include the following:

(i) Improved marine fisheries resource assessment and management;
(ii) Increased production of marine finfish;
(iii) Improved management of inland waters to enhance production;
(iv) Higher value-added fishery products through better fish handling, processing, and marketing practices;
(v) Increased export revenues, principally from expansion of marine finfish exports;
(vi) Increased local consumption of fish products; and
(vii) Increased employment and better incomes in the fisheries sector.

In support of these objectives, the following general policy recommendations have been formulated:

(i) Encouragement of private sector participation in the fishing industry particularly in boatbuilding and repair, ice production and the supply of vessel hulls, engines, parts, and gears;

(ii) Strengthening of Government institutions in planning, resource assessment, resource management, research and training, statistics collection, and extension;

(iii) Better coordination, stronger management, improved discipline, and commitment on the part of Government institutions involved in fisheries;

(iv) Increased investment in fisheries, particularly in:

* Fisheries infrastructure like the construction of additional fishing ports at Guwandan or Sonmiani Bay;

* Inland fisheries and aquaculture including:

- Training of fish farmers;
- Establishment of pilot fish farms and provision of extension services;
- Program to enhance fisheries of reservoirs and lakes through stocking and management, establishment of hatcheries and nurseries, and staff training.

(v) Provision of fisheries credit to increase production of marine fish, expansion of inland fisheries and aquaculture, improved processing and marketing, and investment in new boats, gear, fishponds, equipment, and other facilities.

In line with the development objectives and the policy recommendations listed above, the following policy measures have been lined up for implementation:

(i) Establishment of a Division of Fisheries within the Ministry of Food, Agriculture, and Cooperatives, and strengthening of the Marine Fisheries Department and reconstitution of the Fisheries Advisory Board;

(ii) Major expansion and revision of the fish marketing system;

(iii) Greater use of small pelagics and shrimp by-catch for human consumption and use of mesopelagics for fishmeal, if feasible;

(iv) Development of fishermen's trade organizations as channels for socio-economic development and assistance to fishing communities in the development of fisheries resources, user rights, and management capabilities;

(v) Enforcement of quality control for domestic consumption and export of fish products;

(vi) Expansion of the aquaculture industry to increase production; and

(vii) Implementation of effective fisheries management by control of fishing effort, especially in the shrimp fishery.

6. PAST, PRESENT, AND PIPELINE DEVELOPMENT PROJECTS

6.1. Past Projects

6.1.1 ADB-funded First Aquaculture Development Project

Approved in December 1979 and completed in 1987, this Project had a total cost equivalent to US$221.1 million, of which the ADB loan was US$14.1 million.

This Project supported the development of aquaculture and inland capture fisheries in Sind, Punjab, and NWFP through the provision of hatcheries, training facilities, boats and motors in Punjab, credit for fishponds, marketing facilities and lake fisheries in Sind and Punjab, pilot-scale commercial trout farming in NWFP, and consulting services for all three provinces. Its specified components included the following:

(i)	Punjab (US$4.21 million and additional US$3.25 million from ADBP for credit facilities to private sector)	:	Improvement of hatcheries; fish nursery units; procurement of necessary equipment and technical knowhow; foreign training; consultants; and upgrading of present physical and biological facilities.
(ii)	NWFP (US$519,000)	:	Pilot project for commercial trout farming improvement in trout hatchery at Madyan (Swat); assistance for trout farming on commercial basis; training in hatcheries/farming and technical assistance through consulting services.
(iii)	Sind (Rs. 52.489 million)	:	Development of hatcheries at Chilya and Sukkur; lake fisheries development; pilot project for cage and pen culture; provision of loans to fish farms; establishment of model ponds at Haleji Lake; and establishment of training institute in fish farming and aquaculture aspects.

6.1.2 Fisheries Development in Reservoirs (FAO/TCP/PAK/6657)

This Project, with a total cost of US$226,000, provided assistance in the conduct of biological surveys and limnological and fishery investigations of Pakistan reservoirs (Hub, Khanpur, Mangla, Tarbela, Rawal, and Simly); the determination of the potential of existing hatcheries and assistance in running the existing hatcheries in an efficient

way; formulation of a plan for new hatcheries in Hub, Mangla, and Tarbela; preparation of a project document for a major development project for enhancement of fish stocks in the major reservoirs of Pakistan.

6.1.3 Introduction of Low-Cost Fish Farming in Rural Areas (FAO/TCP/PAK/66)

This small project was executed by the Ministry of Food, Agriculture, and Cooperatives using an FAO contribution of US$36,000. The Project involved the construction of ponds, selection of culture and rearing technology assisted by a consultant, in-service staff, training, and provision of equipment for pond investigations.

6.2 Ongoing Projects

6.2.1 Second Aquaculture Development Project (ADB/PAK/916)

This is the second phase of the ADB-financed Aquaculture Development Project. Started in July 1990 and with a duration of five years, the Project is to be funded out of a US$20-million loan from ADB. It is aimed at providing the required support to the private sector (including fish farmers as well as fishermen operating in inland waters), and at carrying out a number of key development activities that will encourage emerging private sector initiatives in aquacultural production. The major components of the Project are: (i) strengthening the support services; (ii) data collection, surveys, and analysis; (iii) production programs; and (iv) institutional development.

This Project is to be divided into three sub-projects, each of which is to be implemented fairly independently by each province through the Department of Fisheries as executing agency. The allocation to the different provinces is as follows:

Sind	:	US$ 6.0 million
Punjab	:	US$ 8.4 million
NWFP	:	US$ 5.1 million

At the national level, the Federal Ministry of Food, Agriculture, and Cooperatives is the responsible agency.

The main components of the Punjab sub-project are: upgrading of extension services; survey of open waters and management plan; establishment of fish farmer training centers, and an Inland Fisheries Statistics Unit; and provision of foreign training, fellowships, and consulting services.

The main components in Sind Province include: the upgrading of extension services; management of a pilot-scale flood control component; development of shrimp culture; establishment of an Inland Fisheries Statistics Unit; foreign training, fellowships, and consultancy services.

6.2.2 Azad Kashmir Coldwater Fish Culture (PAK/88/048)

This Project started in January 1990 and is being funded by the UNDP at a cost of US$1,398,440. Its immediate objective is to demonstrate the viability of coldwater fish farming in the northern part of Kashmir, specifically in the Neelum Valley. Due to border problems, the Project had to limit itself only to the rehabilitation of one hatchery.

6.3 Pipeline Projects

6.3.1 Fisheries Development in Reservoirs

This Project is aimed at assisting in the enhancement of fish production in reservoirs by implementing a management plan for stocking the reservoirs. It includes the establishment of modern hatcheries at Hub, Mangla, and Tarbela; installation of modern laboratories; staff training in aquacultural aspects and reservoir fisheries management; and establishment of monitoring system for regular data collection. The improvement of fishing conditions and setting up of fishermen's cooperatives, are also intended to be completed through Project activities. After completion, reservoir fish production is expected to be three times higher than present levels. Maximizing the fish production from reservoirs means availability of more fish in inland markets; expansion in fishing industry, i.e., in fish handling, processing, and marketing; and greater manpower involvement, all leading to an improvement in the national economy.

6.3.2 Canadian Assistance to Inland Fisheries

CIDA sent a Mission to identify areas of assistance in inland capture and culture fisheries, with particular attention to the welfare of the fishermen and their families.

6.4 Proposed Projects

In addition to the above pipeline projects, several projects have been proposed by the provincial DOFs and prioritized as follows:

	Priority No. 1	Proponent
(i)	Establishment of fish hatcheries at Larkana and Nawabshah districts	DOF Sind
(ii)	Development of coldwater culture in NA	DOF Northern Area
(iii)	Fisheries development in Chashma reservoir	DOF WAPDA

(iv)	Feasibility preparation for development of warmwater culture in AJK	DOF AJK/Mazaffarabad
(v)	Development of fisheries in NWF	DOF NWFP
	Priority II	
(vi)	Development of fish culture in brackish waters	DOF Sind
(vii)	Development of warmwater fish culture in AJK	DOF AJK
(viii)	Improvement of fishing techniques in deep reservoirs	DOF WAPDA
(ix)	Freshwater shrimp hatchery	DOF Sind
(x)	Technical assistance to fish farmers in NWFP	DOF NWFP
	Priority III	
(xi)	Development of carp hatchery in Baluchistan	DOF Baluchistan
(xii)	Development of fish culture in water-logged areas in Punjab	DOF Punjab

7. CONSTRAINTS TO, AND RECOMMENDATIONS FOR, INLAND FISHERIES DEVELOPMENT

7.1 Riverine Fisheries

A decline in riverine catches has been observed as a result of the diversion of river water for irrigation and the destruction of the fishing grounds of different species. There is scope for increased harvesting efficiency through the use of improved fishing techniques or the use of more efficient gear like fyke or hoop net, in the affected rivers.

Also, as no studies have been conducted in the past to determine the impacts of water diversion on fishery potential and on the biology of the commercially important species, it is recommended that the surveys and investigations to be done in Punjab and Sind under the Second ADB Aquaculture Project, be continued even after the completion of the Project.

7.2 Lake and Reservoir Fisheries

The country's reservoirs and lakes possess good potential for increased production. If managed properly, they could produce an average of 50 kg/ha/yr for an increment of 10,000 mt. In Mangla reservoir, production could go up to 100 kg/ha/yr if managed on a scientific basis. If the stocking demand of 11.2 million fish fingerlings of the WAPDA reservoirs is met, the fish production of these reservoirs could increase by three times to reach 6,000 mt.

The production potential of these lakes and reservoirs has not been fully realized, however, due to factors including: (i) shortage of stock assessment data; (ii) absence of appropriate fishing management plans; and (iii) inadequate supply of suitably-sized fingerlings for stocking; and (iv) use of inappropriate fishing gears.

To optimize fish production and yield from these reservoirs and lakes, it is recommended that a program integrating capture fisheries with aquaculture be implemented. Such a program should have the following components:

(i) Formulation of a management plan consisting of stocking, preservation of breeding grounds, weed control, harvest regulations, and predator control for each waterbody;

(ii) Establishment of hatcheries and nurseries at each reservoir, either in ponds or in pens/cages, in order to produce sufficient fish fry for growing to appropriate sizes for stocking in lakes and reservoir;

(iii) Manpower development or training of DOF personnel in areas relevant to the above to ensure that the management plan is implemented;

(iv) Development of appropriate fishing gears and/or the introduction of modern techniques/methods like the use of fishfinders and attracting and aggregating devices; and

(v) Regular collection and analysis of data on physical, chemical, limnological, fishery biological, and stock assessment for each reservoir, for use as inputs for management planning.

7.3 Aquaculture

7.3.1 Carp Culture

The major constraint to the rapid increase in production from carp culture is the lack of technical information on pond stocking management techniques and stocking plan.

Although the ADBP has provided substantial assistance to the fish farmers by way of extending credit for fishpond development, the lack of training of fish farmers has prevented them from attaining projected yields. The low financial returns have given them inadequate justification for the investments made, especially in large fish farms, and have discouraged them from expanding their operations.

The Government should strengthen training and extension services to fish farmers particularly in pond management and seed production. Model fishfarms have to be established to serve as demonstration and training centers for the ordinary fish farmers. The Government should also set up more carp hatcheries to ensure the production of adequate seed for stocking in ponds, and should provide enough incentives to motivate the private sector to invest in carp hatchery and culture.

7.3.2 Trout Culture

Good production possibilities for trout are found in the Northern Areas, in the Neelum valley of AJK, and in the northwestern areas of NWFP. More trout hatcheries are planned for the Northern Areas to produce fingerlings for stocking in open waters and/or in trout farms.

7.3.3 Shrimp Culture

Recent surveys and the experience of private farmers have shown the technical feasibility of shrimp culture in Pakistan despite constraints such as extreme range of temperature, excessive variation in salinity, unknown availability of postlarvae, environmental degradation, and lack of infrastructure and planning.

Under the first ADB Aquaculture Project, a pilot shrimp farm was supposed to have been established in the Sind Delta to test the feasibility of shrimp farming. However, its operation has been delayed. The Second ADB Aquaculture Project includes extension services for the development of white shrimp culture. The private sector is to be motivated to undertake shrimp farming and hatchery establishment. Under the Second Aquaculture Project, a shrimp hatchery has been proposed to produce seven million postlarvae. More options are available to shrimp farmers using white shrimp whose seed is available locally.

7.3.4 Support Services and Facilities

The infrastructural and institutional facilities at research centers like the Pakistan Agricultural Research Council at Islamabad and the Fisheries Research and Training Center at Lahore have to be further improved and strengthened and research on fish and fishery biology, reproductive physiology, ecology, and fish nutrition and pathology need to be carried out.

The existing rules and procedures for acquisition of unreserved state land, sanction of loans from ADBP, hiring of bulldozers from Agricultural Engineering Department, sanction of canal water from the Irrigation Department for fish farms, sanction of electricity connection for tube wells, are all extremely cumbersome, time-consuming, and discouraging. The concerned procedures need to be simplified. The sanction of electrical connections for fisheries tube wells should be made easier and charged at the same rates as for agricultural tube wells. Also, the prevailing interest rates on loans for fish farming are very high and need to be reduced to bring them at par with those applicable to the agriculture sector.

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ANNEX A

CHECKLIST OF FRESHWATER FISH IN PAKISTAN
E = Exotic; C = Common; R = Rare

	Scientific Name	Distribution in Pakistan	Distribution outside Pakistan
	ORDER CLUPEIFORMES		
	FAMILY CLUPEIDAE		
1.	*Gudusia chapra*	NWFP (R), Punjab Sind (C), Baluchistan (R)	India, Bangladesh
2.	*Hilsa ilisha*	Sind (C), Baluchistan (R)	Iraq, Iran, India, Baluchistan, Burma, Sri Lanka
	ORDER OSTEOGLOSSIFORMES		
	FAMILY NOTOPTERIDAE		
3.	*Notopterus notopterus*	NWFP (R), Punjab Sind (C),	India, Bangladesh, Burma, Thailand, Malaysia, Indonesia,
4.	*Notopterus chitala*	Punjab (C), Sind (C)	India, Bangladesh, Burma, Thailand, Malaysia, Indonesia, Philippines
	ORDER SALMONIFORMES		
	FAMILY SALMONIDAE		
5.	*Salmo trutta fario*	Northern Area (C), NWFP (C), Baluchistan (R), Azad Kashmir	Introduced in almost all the countries of the world in suitable habitats
6.	*Oncorhynchus mykiss*	NWFP (R)	Introduced in most countries of the world in suitable habitats
	ORDER CYPRINIFORMES		
	FAMILY CYPRINIDAE		
7.	*Securicula gora*	Punjab (C), Sind (C)	India, Bangladesh
8.	*Salmostoma bacaila*	NWFP (C), Punjab (C), Sind (C), Baluchistan (R) Azad Kashmir	Kashmir, Nepal, India, Bangladesh
9.	*Salmostoma punjabensis*	NWFP (C), Punjab (C), Sind (C), Baluchistan (R)	
10.	*Chela cachius*	NWFP (C), Punjab (C), Sind (C), Baluchistan (R)	India, Bangladesh, Burma
11.	*Chela laubuca*	Punjab (R), Sind (R)	India, Nepal, Bangladesh, Burma, Thailand, Malaysia, Indonesia

Scientific Name	Distribution in Pakistan	Distribution outside Pakistan
12. *Barilius vagra pakistanicus*	NWFP (C), Punjab (C), Sind (C), Baluchistan (C)	India
13. *Barilius bendelisis*	Punjab (R), Sind (R)	India, Nepal, Bangladesh, Sri Lanka
14. *Barilius modestus*	NWFP (R), Punjab (C), Sind (R), Baluchistan	India, Nepal
15. *Rasbora daniconius*	NWFP (R), Punjab (C), Sind (R)	India, Bangladesh, Burma, Malaysia, Thailand, Sri Lanka
16. *Danio devario*	NWFP (C), Punjab (R), Sind (R), Baluchistan (R)	India, Nepal, Bangladesh, Burma
17. *Brachydanio rerio*	NWFP (R)	India, Nepal, Bangladesh, Burma
18. *Esomus danricus*	Punjab (C), Sind (C)	India, Nepal, Bangladesh, Burma, Thailand, Malaysia, Indonesia, Sri Lanka
19. *Labeo rohita*	NWFP (R), Punjab (C), Sind, Baluchistan (R)	India, Bangladesh, Burma
20. *Labeo calbasu*	NWFP (R), Punjab (C), Sind, Baluchistan (R)	India, Nepal, Bangladesh, Burma, Thailand
21. *Labeo gonius*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh, Burma
22. *Labeo dero*	NWFP (R), Punjab (C), Sind (C), Baluchistan	India, Bangladesh, Nepal, Sri Lanka
23. *Labeo fimbriatus*	Punjab (R), Sind (R)	India
24. *Labeo pangusia*	Sind (R)	India, Bangladesh
25. *Labeo bata*	Sind (R)	Nepal, India, Bangladesh
26. *Labeo boggut*	Punjab (R), Sind (R)	India
27. *Labeo boga*	Punjab (R)	India, Nepal, Bangladesh, Burma
28. *Labeo caeruleus*	Punjab (R), Sind (R) Baluchistan (R)	– –
29. *Labeo dyocheilus*	NWFP (C), Punjab (C), Sind (R), Baluchistan (R)	India
30. *Labeo nigripinnis*	NWFP (R), Punjab (R), Sind (R)	–
31. *Labeo gedrosicus*	Baluchistan (R)	–
32. *Labeo macmahoni*	Baluchistan (R)	–
33. *Cirrhinus mrigala*	NWFP (R), Punjab (C), Sind (C), Baluchistan (R)	India, Bangladesh, Burma
34. *Cirrhinus reba*	NWFP (R), Punjab (C), Sind (C), Baluchistan (R)	Nepal, India, Bangladesh, Burma, Thailand

Scientific Name	Distribution in Pakistan	Distribution outside Pakistan
35. *Crossocheilus diplocheilus*	NWFP (R), Punjab (C), Sind (C), Baluchistan (R)	Iran, Afghanistan, India
36. *Garra gotyla*	NWFP (C), Punjab (C), Sind (R), Baluchistan (C)	India, Nepal, Bangladesh, Burma
37. *Garra wanae*	NWFP (R)	
38. *Garra rossica*	Baluchistan (C)	Afghanistan, Iran, USSR
39. *Aspidoparia morar*	NWFP (R), Punjab (C), Sind (C), Baluchistan (C)	Iran, India, Nepal, Bangladesh, Burma, Thailand
40. *Osteobrama cotio*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh
41. *Tor tor*	NWFP (R), Punjab (R)	India, Bangladesh Burma
42. *Tor putitora*	NWFP (C), Punjab (C) Sind (R), Baluchistan (C)	Nepal, India, Bangladesh
43. *Tor mosal*	NWFP (R), Punjab (R)	India
44. *Tor zhobensis*	NWFP (C), Baluchistan (R)	-
45. *Puntius sarana*	NWFP (R), Punjab (C), Sind (C), Baluchistan (R)	India, Bangladesh, Nepal
46. *Puntius chola*	NWFP (C), Punjab (C), Sind (C)	Nepal, India, Bangladesh, Burma
47. *Puntius sophore*	NWFP (C), Punjab (C), Sind (C), Baluchistan (R)	Nepal, India, Bangladesh, Burma
48. *Puntius ticto*	NWFP (C), Punjab (C), Sind (C), Baluchistan (C)	India, Bangladesh, Burma, Thailand, Sri Lanka
49. *Puntius conchonius*	Punjab (R)	India, Bangladesh
50. *Puntius terio*	Punjab (R), Baluchistan (R)	India, Bangladesh
51. *Puntius phutunio*	Sind (R)	India, Bangladesh, Burma, Sri Lanka
52. *Puntius gelius*	Sind (R)	India, Bangladesh
53. *Puntius vittatus*	Sind (?)	India, Bangladesh, Sri Lanka
54. *Puntius punjabensis*	NWFP (R), Punjab (R), Sind (R), Baluchistan (R)	India
55. *Puntius waageni*	Punjab (R)	India
56. *Cyprinion wastoni*	NWFP (R), Punjab (R), Sind (R), Baluchistan (R)	Iran, Afghanistan
57. *Cyprinion watsoni*	Baluchistan (R)	Iran, Afghanistan, Arabia
58. *Cyprinion milesi*	Baluchistan (R)	Iran
59. *Copoeta capoeta heratensis*	Baluchistan (R)	
60. *Schizothorax richardsonii plagiostomus*	Northern Areas (C), NWFP (C), Punjab (R), Baluchistan (R)	India, Afghanistan
61. *Schizothorax skarduensis*	Northern Areas (R)	

	Scientific Name	Distribution in Pakistan	Distribution outside Pakistan
62.	*Schizothorax progastus labiatus*	Northern Areas (C), NWFP (C), Punjab (R), Baluchistan	Afghanistan
63.	*Schizothorax esocinus*	Northern Areas (R), NWFP (R)	Afghanistan
64.	*Schizothorax nasus*	Northern Areas (R)	
65.	*Schizothorax longipinnis*	Northern Areas (R)	
66.	*Schizothorax intermedius*	Northern Areas (R)	Afghanistan, USSR, China
67.	*Schizocypris brucei*	NWFP (R), Baluchistan (R)	Iran, Afghanistan
68.	*Diptychus maculatus*	Northern Areas (R)	Afghanistan, India, USSR, China
69.	*Diptychus pakistanicus*	Northern Areas (R)	–
70.	*Ptychobarbus conirostris*	Northern Areas (R)	Afghanistan
71.	*Schizopygopsis stoliczkai*	Northern Areas (R)	Afghanistan, Iran, USSR, China, India
72.	*Cyprinus carpio*	NWFP (C), Punjab (C), Sind	Introduced in almost all the countries
73.	*Carassius auratus*	NWFP (R), Punjab (C), Sind (C), Baluchistan (R)	Introduced in almost all the countries
74.	*Ctenopharyngodon idella*	Punjab (R), Sind (R)	Introduced in most of the countries
75.	*Catla catla*	NWFP (C), Punjab (C), Sind (C)	India
76.	*Amblypharyngodon mola*	NWFP (C), Punjab (C), Sind (C)	
	FAMILY COBITIDAE		
77.	*Botia rostrate*	Punjab (R), Sind (R), Baluchistan (R)	India
78.	*Botia lohachata*	Punjab (C), Sind (C), Baluchistan (R)	India, Bangladesh
79.	*Botia birdi*	NWFP (R)	India
80.	*Acanthocobitis botius*	NWFP (C), Punjab (C), Sind (R), Baluchistan (R)	India, Nepal, Bangladesh, Sri Lanka
81.	*Noemacheilus corica*	NWFP (R), Punjab (C)	India, Nepal, Bangladesh
82.	*Triplophysa stoliczkae*	Northern Areas (R), NWFP (R)	Afghanistan, Iran, Kashmir, China, India
83.	*Triplophysa tenuicauda*	Northern Areas (R)	–
84.	*Triplophysa gracilis*	Northern Areas (R)	–
85.	*Triplophysa yasinensis*	Northern Areas (R)	–
86.	*Triplophysa brahui*	Baluchistan (C)	–
87.	*Triplophysa griffithi naziri*	NWFP (R)	–

	Scientific Name	Distribution in Pakistan	Distribution outside Pakistan
88.	*Triplophysa griffithi hazaraensis*	NWFP (R)	–
89.	*Triplophysa stenurus choprai*	NWFP (R)	–
90.	*Schistura kessleri kessleri*	Baluchistan (C)	Iran, Afghanistan
91.	*Schistura kessleri lepidocaulis*	NWFP (R), Punjab (R)	–
92.	*Schistura punjabensis*	Punjab (R)	India
93.	*Schistura prashari*	NWFP (C), Punjab (R)	–
94.	*Schistura lindbergi*	Punjab (R), Baluchistan (C)	–
95.	*Schistura anambarensis*	Baluchistan (R)	–
96.	*Schistura machensis*	Baluchistan (R)	–
97.	*Schistura harnaiensis*	Baluchistan (R)	–
98.	*Schistura pakistanica*	Baluchistan (R)	–
99.	*Schistura akeoidota*	NWFP (C)	–
100.	*Schistura halbanti*	Punjab (R), Azad Kashmir (C)	–
101.	*Schistura naseeri*	NWFP (C)	–
102.	*Schistura arifi*	Baluchistan (R)	–
103.	*Schistura curtistigma*	NWFP (R)	–
104.	*Schistura macrolepis*	Punjab (R)	–
105.	*Schistura afasciatae*	NWFP (R)	–
106.	*Schistura fascimaculatae*	NWFP (R)	–
107.	*Schistura kohatensis*	NWFP (R)	–
108.	*Schistura shadiwalensis*	NWFP (R)	–
109.	*Schistura microlabra*	NWFP (R)	–
110.	*Lepidocephalus guntea*	NWFP (R)	India, Nepal, Bangladesh
	ORDER SILURIFORMES		
	FAMILY BAGRIDAE		
111.	*Rita rita*	NWFP (R), Punjab (C), Sind (C), Baluchistan (R)	India, Bangladesh, Burma
112.	*Aorichthys aor*	Punjab (R), Sind (R)	India, Bangladesh, Burma
113.	*Aorichthys seenghala*	NWFP (R), Punjab (C), Sind (C), Baluchistan (R)	India, Bangladesh,
114.	*Mystus cavasius*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh, Burma, Thailand Indonesia

	Scientific Name	Distribution in Pakistan	Distribution outside Pakistan
115.	*Mystus bleekeri*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh, Burma
116.	*Mystus tengara*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh,
117.	*Mystus vittatus*	Punjab (C), Sind (C)	India, Nepal, Bangladesh, Burma, Thailand, Sri Lanka
118.	*Mystus horai*	Punjab (R)	–
	FAMILY SISORIDAE		
119.	*Sisor rhabdophorus*	Punjab (R), Sind (R)	India, Bangladesh
120.	*Bagarius bagarius*	Punjab (C), Sind (R)	India, Bangladesh, Burma, Thailand, Malaysia, Indonesia, South China
121.	*Gagata cenia*	NWFP (C), Punjab (C), Sind (C)	India, Bangladesh, Burma, Thailand
122.	*Nangra nangra*	Punjab (R)	India
123.	*Nangra robusta*	Punjab (R)	–
124.	*Glyptothorax telchitta sufii*	Punjab (R)	–
125.	*Glyptothorax cavia*	NWFP (R), Punjab (C), Sind (R)	India, Bangladesh, Burma
126.	*Glyptothorax pectinopterus*	–	India
127.	*Glyptothorax naziri*	NWFP (C), Punjab (R), Baluchistan (R)	–
128.	*Glyptothorax punjabensis*	NWFP (C), Punjab (C)	–
129.	*Glyptothorax Kashmirensis*	–	India
130.	*Glyptothorax stocki*	NWFP (R), Punjab (R) Azad Kashmir	–
131.	*Glyptosternum reticulatum*	Northern Areas (C), NWFP (R)	Afghanistan, India, USSR
	FAMILY SCHILBEIDAE		
132.	*Clupisoma garua*	Punjab (C), Sind (C)	India, Bangladesh
133.	*Clupisoma naiziri*	NWFP (C), Punjab (R)	–
134.	*Pseudeutropius atherinoides*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh, Burma
135.	*Eutropiichthys vacha*	Punjab (C), Sind (C)	India, Bangladesh, Burma, Thailand
136.	*Ailia coila*	Punjab (C), Sind (C)	India, Bangladesh
137.	*Ailia punctata*	Punjab (C), Sind (C)	India, Bangladesh
	FAMILY AMBLYCIPITIDAE		
138.	*Amblyceps mangois*	Punjab (R)	India, Bangladesh, Burma, Thailand
	FAMILY SILURIDAE		
139.	*Wallago attu*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh, Burma, Thailand, Sri Lanka, Malaysia, Indonesia, China

Scientific Name	Distribution in Pakistan	Distribution outside Pakistan
140. *Ompok bimaculatus*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh, Burma, Thailand, Indonesia
141. *Ompok padba*	NWFP (C), Punjab (C), Sind (R)	India, Bangladesh
FAMILY BADIDAE		
142. *Badis badis*	Punjab (R), Sind (C)	India, Nepal, Bangladesh, Burma
FAMILY CICHLIDAE		
143. *Oreochromis mossambicus*	NWFP (R), Punjab Sind (C), Baluchistan (R)	Introduced in many countries
FAMILY MUGILIDAE		
144. *Sicamugil cascasia*	NWFP (R), Punjab (C), Sind (C)	India
FAMILY GOBIIDAE		
145. *Glossogobius gutum*	NWFP (R), Punjab (C), Sind (C), Baluchistan (R)	India, Bangladesh, Andamans, Malaysia, Thailand, China, Japan, Philippines, Indonesia, Australia, East Africa, South Pacific Islands
FAMILY ANABANTIDAE		
146. *Colisa fasciata*	NWFP (R), Punjab (C), Sind (C)	India, Nepal, Bangladesh, Burma
147. *Colisa lalia*	NWFP (R), Punjab (C), Sind (C)	India, Bangladesh
FAMILY MASTACEMBELIDAE		
148. *Mastacembelus armatus*	NWFP (C), Punjab (C), Sind (C), Baluchistan (R)	India, Nepal, Bangladesh, Burma, Thailand, Kampuchea, South China, Malaysia, Indonesia, Sri Lanka
149. *Mastacembelus pancalus*	Punjab (C), Sind (C)	India, Bangladesh
150. *Macrognathus aculeatus*	Punjab (R), Sind (R)	India, Bangladesh, Burma, Thailand, Malaysia, Indonesia
ORDER SYNBRANCHIFORMES		
FAMILY SYNBRANCHIDAE		
151. *Monopterus cuchia*	Punjab (R), Sind (R)	Nepal, India, Bangladesh, Burma

INTERSESSIONAL ACTIVITIES IN INLAND FISHERIES IN PAPUA NEW GUINEA

by

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The Department of Fisheries and Marine Resources of Papua New Guinea (PNG) has suggested to its Government that it may be appropriate for the nation to join the Indo-Pacific Fisheries Commission (IPFC) in order to enjoy the full advantages of membership. The Government is presently considering such a move.

Inland fisheries remain primarily of a subsistence nature in PNG with the exception of the barramundi (*Lates calcarifer*) fishery in rivers in the south of the country. Overall, developments have been relatively static in the last three years. It is noteworthy, though, that the Government has become increasingly aware of the importance of inland subsistence fisheries and inland commercial fishery development. Consequently, more attention is being given to this sector in longer-term fisheries planning, budgetary allocations, and priorities.

The main inland fisheries development activity at present involves the Sepik River Fish Stock Enhancement Project executed by FAO in collaboration with the PNG Department of Fisheries and Marine Resources. The Project has now entered its second phase which involves stocking of inland waters in the Sepik and Ramu River basin in the north of the country. As previously reported, the Project has been closely adhering to the code of practice (Turner, 1988) regarding species transfers. By closely following code procedures, an independent advisory group consisting of eight members unanimously endorsed a recommendation made by the Project in 1990 to stock the river basin. Further evaluations, in close collaboration with the advisory group, have resulted in the approval of the stocking of all species so far recommended by the Project Team, namely: *Tilapia rendalli* (obtained from the Institute of Aquaculture at Stirling University) and *Trichogaster pectoralis* and *Osphronemus gouramy* (both already present in drainages in the south of PNG). *T. rendalli* has already been imported and stocking of the F_1 generation has commenced, while the transfer of *O. gouramy*, although approved under code procedures, has been suspended due to doubts over its potential impact on fish production in natural waters. A number of other fish species are in the

final stages of evaluation. The evaluation of coldwater (higher altitude) fisheries and methods of their stocking, are noted as problematic areas in view of the paucity of information on fisheries in non-floodplain regions of river basins in the tropics.

Nevertheless, the Project has noted the great importance of such fisheries in the Sepik and Ramu River basin. Although tributary streams/rivers are possibly less productive than some lowland environments, they encompass a far greater resource area. The majority of people living within the Sepik/Ramu basin are dependent upon higher altitude rivers, streams, and lakes as their sole fishery resource. These conclusions endorse previous recommendations by the IPFC Working Party of Experts on Inland Fisheries pertaining to coldwater fisheries.

The Sepik Project has gained much experience in the appraisal of fish transfers. One problem area encountered, however, concerns quarantine aspects of fish transfers. The Project has noted the potential for utilizing quarantine facilities at the source of stocks, or via a third party, in cases where the recipient country has more limited fish quarantine expertise or facilities. Numerous publications relating to many aspects of the Sepik/Ramu River basin fishery are available from the Project.

REFERENCE

Turner, G. E. (1988). Codes of practice and manual of procedures for consideration of introductions and transfers of marine and freshwater organisms. *FAO/ EIFAC/CECPI Occasional Paper* 23:44p.

RECENT TRENDS IN THE INLAND FISHERY OF SRI LANKA

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1. INTRODUCTION

The inland fishery of Sri Lanka, which is almost entirely based on its reservoir systems, is considered to be one of the most productive in the world. The total fish yield from the larger reservoirs is 27,000-30,000 mt/yr, which is equivalent to over 300 kg/ha/yr (De Silva, 1988a). When compared to the average annual yield of 80 kg/ha of lake and reservoir fisheries in lowland areas of tropical developing countries (Oglesby, 1985), the mean production from the Sri Lankan reservoir fishery is very high. The inland fishery of Sri Lanka at present accounts for about 20 per cent of the country's total fish production (De Silva, 1988a).

The extant reservoirs in Sri Lanka consist of the ancient reservoirs that have been restored or rehabilitated, and the new reservoirs. The total surface area of these reservoirs at full supply level is about 175,000 ha (Fernando and De Silva, 1984) which gives a value of approximately 2.7 ha of water surface for every sq km of land. By the end of this century, with the prospects for the construction of new reservoirs, the total area of reservoirs will be over 250,000 ha, giving four ha per sq km of standing water for the country as a whole (Fernando, 1991). Due to the extensive availability of inland water resources in Sri Lanka, there is considerable potential for the development of inland fishery in the country. This is particularly important because the reservoir fishery in Sri Lanka is a cheap source of high-quality animal protein for rural communities.

This paper reviews recent trends in the inland fishery of Sri Lanka and attempts to identify future strategies for its development.

2. THE INLAND FISHERY OF SRI LANKA

The inland water resources of Sri Lanka include 103 perennial rivers, of which 23 rivers have a catchment area of over 500 sq km, floodplains with a total area of around 40,800 ha, and a multitude of ancient and new reservoirs (Mendis, 1977; De Silva, 1987a). Despite the extensive availability of different types of freshwater bodies, the inland fishery is almost entirely a capture fishery, particularly in the perennial reservoirs.

The inland fishery in Sri Lanka is a relatively recent development which evolved after the introduction of the exotic cichlid species *Oreochromis mossambicus* in 1952. As such, it is not scientifically managed as in most of Asia. Its growth has been documented by various workers (e.g., Fernando and Indrasena, 1969; Fernando, 1971, 1977, 1984; De Silva, 1983a, 1985, 1987a), and a comprehensive account on the reservoirs of Sri Lanka and their fisheries has been prepared by De Silva (1988a).

2.1 The Freshwater Fish Fauna and Inland Capture Fishery

As cited by different authors, the indigenous fish species in Sri Lanka number between 51 and 65 and belong to 15 families (Mendis and Fernando, 1962; Fernando and Indrasena, 1969; De Silva, *et al.*, 1981; De Silva, 1988a; Pethiyagoda, 1991). Over 50 per cent of the freshwater fish species in the country belongs to the family Cyprinidae. New records of three species of Cyprinidae, namely, *Puntius asoka* (Kottelat and Pethiyagoda, 1989a), *Danio pathirana* (Kottelat and Pethiyagoda, 1990), and *Barbus srilankensis* (Senanayake, 1985), are found in the literature. A new species of the family Gobiidae, *Schismatogobius deraniyagalai*, in Sri Lanka has also been recorded by Kottelat and Pethiyagoda (1989b).

From the various publications, it is evident that since the first introduction of *Salmo trutta* from Europe in 1882, 19 exotic species belonging to four families, of which Cichlidae and Cyprinidae are the best represented, have been introduced into Sri Lankan freshwaters (Fernando, 1971; Balasuriya *et. al.,* 1983; Chandrasoma, 1983; De Silva, 1987a). A complete updated list of fish species introduced into Sri Lankan freshwaters is given by De Silva (1988a) but does not include the exotic ornamental fish species for which proper records on introductions are not available.

Some 41 species belonging to 12 families are recorded in the reservoir fish fauna of Sri Lanka (Table 1). Nevertheless, only two species of cyprinids (*Labeo dussumieri* and *B. sarana*) and four species of cichlids (*O. mossambicus, O. niloticus, Tilapia rendalli,* and *Etroplus suratensis*) are common in commercial catches (De Silva, 1983b; Amarasinghe and Pitcher, 1986).

The species composition of the landings of the reservoir fishery is mainly determined by the efficiency of fishing gear. In most Sri Lankan reservoirs, due to the presence of impediments to fishing (i.e., submerged decaying tree stumps), the use of fishing gear other than gillnets is virtually impossible. Also, the minimum permissible mesh size of gillnets (7.5 cm) in the reservoir fishery of Sri Lanka, which has been imposed by the Ministry of Fisheries (MOF) to control the landing size of *O. mossambicus*, prevents exploitation of small-sized species. Amarasinghe and Samarakoon (1988) have shown that *E. suratensis* and *T. rendalli* are poorly caught in gillnets due to their restricted movements associated with reproductive behavior. Fernando (1987) also reported that beach seining was more effective than gillnetting for catching indigenous species including *E. suratensis.*

Table 1

List of fish species recorded from Sri Lankan perennial reservoirs

Family Species	Remarks	Authors
A. Anguillidae		
1. *Anguila bicolor*	++	a, b, d
2. *A. nebulosa*	++	a, b, d, j
B. Cyprinidae		
3. *Amblypharyngodon melettinus*	+	b, e, g
4. *Danio aequipinnatus*	+	b, e, g
5. *Esomus dandrica thermoicos*	+	b, e, g
6. *Rasbora daniconius*	+	b, e, g
7. *Ehirava fluviatilis*	+	b, c
8. *Barbus ticto*	+	g
9. *B. chola*	+	b, e, g
10. *B. filamentosus*	+	b, e, g
11. *B. dorsalis*	+	b, e, g
12. *B. sarana*	++, @	a, d, f, j
13. *Labeo dussumieri*	++, @	a, d, f
14. *L. rohita**	++	f, h, j
15. *Cirrhinus mrigala**	++	f, h
16. *Ctenopharyngodon idellus**	++	f
17. *Cyprinus carpio**	++	f, j
18. *Aristichthys nobilis**	++	h
19. *Hypopthalmichthys molitrix**	++	h
20. *Catla catla**	++	h
21. *Tor khudree longispinnis*	++	i, j
C. Bagridae		
22. *Macrones vittatus*	+	b, e, g
23. *M. kelatius*	+	b, e, g
24. *M. gulio*	+	e
D. Siluridae		
25. *Wallago attu*	++	a, b, d, f
26. *Ompok bimaculatus*	++	a, b, d, f, j
E. Heteropneustidae		
27. *Heteropneustes fossilis*	+	a, b, e, g
F. Clariidae		
28. *Clarias teysmanni*	++	a, i
G. Mastacembelidae		
29. *Mastacembelus armatus*	+	a, b, e, g
H. Hemiramphidae		
30. *Hyporamphus gaimardi*	+	b, e, g
I. Ophicephalidae		
31. *Ophicephalus straitus*	++	a, d, f
32. *O. marulius*	++	j
J. Cichlidae		
33. *Etroplus maculatus*	+	b, e, g
34. *E. suratensis*	++, @	a, d, f
35. *Oreochromis mossambicus**	++, @	a, d, f, j
36. *O. niloticus**	++, @	a, d, f, j
37. *Tilapia rendalli**	++, @	a, d, f, j
K. Anabantidae		
38. *Anabas testudineus*	+	b, e, g
39. *Trichogaster pectoralis**	+	a, g
40. *Osphronemus goramy*	++	a, i
L. Gobiidae		
41. *Glossogobius giuris*	++	a, d, f, j

* exotic species; ++ - fish caught in the commercial fisheries; = - fish species reported from the experimental fishing trials with catches; @ - common species in the commercial catches; b - Schiemer (1983); c - Newrkla and Duncan (1984); d - Amarasinghe and Pitcher (1986); e - De Silva and Sirisena (1987); f - Amarasinghe and Samarakoon (1988); g - Amarasinghe (1990); h - Hettiarchchi

In some reservoirs such as Soraborawewa, Kaudulla, Tabbowa, and Maduru Oya, *O. niloticus* is the dominant species (Chandrasoma, 1986; Amarasinghe, 1988a, 1989) in contrast to most Sri Lankan reservoirs where *O. mossambicus* accounts for over 70 per cent of the total landings (De Silva, 1985) (Table 2). Chandrasoma (1986) suggested that the dominance of *O. niloticus* in Soraborawewa reservoir is due to the abundance of blue-green algae, the preferred and utilizable food of *O. niloticus*. On the other hand, De Silva (1988a) explained that as both *O. mossambicus* and *O. niloticus* are known to digest and assimilate blue-greens, even if not with equal efficiency, the abundance of blue-green algae is probably not the reason for the dominance of *O. niloticus* in Soraborawewa. Also, as Myxophyceae is the most common phytoplankton group in Sri Lankan reservoirs (Amarasinghe *et al.*, 1983; Daniel *et. al.*, 1988), the explanation put forward for the dominance of *O. niloticus* in some reservoirs is far from conclusive.

Table 2
Annual yield and percentage contribution of *O. mossambicus* and *O. niloticus* to the total catch in some reservoirs of Sri Lanka

Reservoir/Year	Annual yield (kg/ha)	% contribution		Source
		O. mossambicus	*O. niloticus*	
Parakrama Samudra				
1982-1983	120	85.5	02	Amarasinghe (in press)
1985	46	70.8	5.6	- do -
1986-1987	40	53.4	24.5	- do -
1989 May	na	33.4	64.6	- do -
Pimburettewa				
1985	432	90	insignificant	Amarasinghe (1987)
1988 (Nov)	na	na	81.9	Amarasinghe (1989)
Kaudulla				
1979 -1982	198	62.1	very low	De Silva (1985
1986-1989	192	15.8	79.6	Personal observations
Minneriya				
1979 -1982	200	67.0	very low	De Silva (1985)
1986-1989	130	61.3	28.6	Personal observations
Soraborawewa				
1980	na	57.4	39.7	Chandrasoma (1986)
1981	na	29.4	69.1	- do -
1982	na	5.9	91.2	- do -
1983	na	75.0	10.0	- do -
1984	na	67.6	30.0	- do -

na = not available.

2.2 Fishing Effort and Fish Yields in Major Reservoirs

De Silva (1988a) has shown that in the fisheries of most major perennial reservoirs, the effort has been increasing over the last decade and that the overall mean effort per unit area (i.e., fishing intensity) in the reservoir fishery has increased from 0.019 craft/ha in 1978 to 0.050 craft/ha in 1984, nearly a three-fold increase in a span of six years.

The number of fishing crafts allocated in the major reservoirs of Sri Lanka is determined by the Ministry of Fisheries (MOF) depending on official fish production statistics, which seem to be unrealistic and are probably overestimated compared to the average annual fish yield estimates based upon field studies of catch and effort for the majority of the crafts actually fishing (Table 3).

Table 3
Official and survey data on fish yields (kg/ha/yr) in four Sri Lankan reservoirs

Year	Reservoirs			
	Kaudulla (2713 ha)	Minneriya (2,511 ha)	Parakrama Samudra (2,662 ha)	Pimburettewa (830 ha)
Official data a				
1980	287.9	197.7	507.3	618.5
1981	127.9	124.2	371.4	594.1
1982	130.8	257.5	185.9	315.9
1983	162.1	255.5	280.8	717.7
1984	415.5	258.7	171.2	884.6
1985	546.9	425.5	120.2	671.0
1986	590.3	461.0	129.0	391.7
1987	266.5	479.3	114.7	434.0
Survey data				
1982-83	-	-	120.0b	-
1985	-	-	46.0c	441.0d
1986-89	192.0e	130.0e	-	-

Sources: a - Ministry of Fisheries, Sri Lanka: b - Amarasinghe and Pitcher (1986); c - Amarasinghe and Samarakoon (1988); d - Amarasinghe (1987); e - Amarasinghe and De Silva (in press).

Chandrasiri (1986) also stated that in five reservoirs in southern Sri Lanka, MOF fish production figures were 2.7 times higher than those in his study and that his values were more realistic than those of the official sources. If indeed, the fishery statistics for the Sri Lankan reservoir fishery are overestimated, this could lead to overexploitation through an increase in fishing effort above the optimal level, which will result in a lowering of catch per unit effort (CPUE) and discourage the true fishermen who depend on the fishery for their livelihood. It has been recorded that in some Sri Lankan reservoirs, *O. mossambicus* stocks have been overexploited (Amarasinghe, 1988a; De Silva, 1988a). It is apparent that there is a need to adopt more efficient procedures in the collection of reservoir fishery statistics in the country. Accurate fishery statistical returns are useful not only for stock assessment but also for investment planning and economic analysis, and for social and nutritional studies (Caddy and Bazigos, 1985).

The collection of fishery statistics in scattered Sri Lankan reservoirs situated in the rural areas is rather difficult (De Silva, 1988). It was suggested that the active involvement of fishermen themselves in the submission of accurate statistics, either individually or through the cooperative societies with which they are affiliated, is useful to overcome this problem (De Silva, 1988).

In the Sri Lankan reservoir fishery, total fish production estimates based upon stratified random sampling according to fish methods, species, fishing areas, and seasons, are found to be more accurate than the non-stratified estimates (Amarasinghe and Pitcher, 1986; Amarasinghe and Samarakoon, 1988; Amarasinghe and De Silva, in press). As such, it is necessary to revise the existing reservoir fishery statistics-collecting procedure of the Ministry of Fisheries. Amarasinghe (in press) has also shown that due to the high variability of catch rates among the fishing crafts in reservoirs, almost all the crafts should be sampled in order to get more precise estimates of the total fish production, unless a stratified random sampling procedure is adopted.

3. CULTURE-BASED FISHERY AND FUTURE DEVELOPMENT

In Sri Lanka, the culture-based fishery is only at the experimental stage. The experimental culture techniques for freshwater fish in the country include: (i) fish culture in seasonal tanks; (ii) fish culture in ponds; and (iii) cage culture.

Carps have been shown to be suitable for culture-based fisheries in Sri Lanka since Chinese and Indian carp postlarvae could be obtained throughout the year for rearing and for stocking in reservoirs although in varying intensities depending on the season of the year (Tennakoon *et al.*, 1988; De Silva, 1988a). Moreover, experimental trials have shown that both Chinese and Indian carps are desirable species for polyculture in seasonal tanks (Chakrabarty and Samaranayake, 1983; Chandrasoma and Kumarasiri, 1986).

3.1 Seasonal Tanks

Seasonal tanks are generally small reservoirs (<80 ha) that store water for six to ten months of the year. There are around 50,000 seasonal tanks in Sri Lanka which cover more than 100,000 ha (Fernando and De Silva, 1984). These tanks were built to supply water for irrigation and domestic user although experiments on their use for aquaculture have been carried out by MOF since 1979. In 1988, Beveridge and Phillips reported a production of 422 mt, representing 1.3 per cent of the country's total freshwater fish production, and a yield of 372 kg/ha/yr from 1,137 ha of seasonal tanks.

Results of carp polyculture trials in 15 seasonal tanks in 1983-1984 showed that it is possible to attain an average yield of 891.5 kg/ha per growing season of nine months (Chandrasoma and Kumarasiri, 1986). In 11 of the 15 tanks, bighead, *rohu*, grass, *mrigal*, and common carp were stocked at 35, 25, 5, 17.5, and 17.5 per cent, respectively; in the four other tanks, bighead carp was stocked at 30 per cent and *catla* was added at five per cent of total. The stocking density ranged between 200-300 fingerlings/ha and the size of fingerlings at stocking was 6.8 cm. It is interesting to note that the tilapias contributed significantly to total fish production in most seasonal tanks although they were not deliberately stocked (Table 4).

Table 4

Fish yields and species composition in 15 seasonal tanks in a single growing season (Sept/Oct 1983 to July/Aug 1984) (from Chandrasoma and Kumarasiri, 1986).

Seasonal tank	Areas (ha)	Yield (kg/ha)	% species composition						
			Bighead carp	Catla	Rohu	Common carp	Mrigal	Common carp	Tilapia
Weheragala	9.0	680.8	24.8	-	34.7	18.9	3.3	2.4	15.8
Bogaswewa	6.0	775.5	23.9	-	24.8	24.3	18.4	3.0	5.4
Karametiwewa	2.4	858.5	12.2	-	34.1	27.8	20.7	1.0	4.1
Angunukolawewa	3.6	445.5	34.0	-	48.4	0.2	13.9	0.7	2.8
Nikawewa	6.0	668.5	49.4	-	20.9	4.1	23.4	0.5	1.7
Welapahala	2.5	785.8	16.8	-	17.8	15.5	21.1	8.2	20.5
Komaligama	3.0	899.0	24.3	-	44.8	18.5	5.9	7.1	-
Epitagoda	3.5	750.0	64.4	8.5	1.9	3.0	5.5	0.7	15.7
Tunkama	4.0	2303.5	37.5	8.6	17.1	11.6	16.8	0.7	7.7
Mahawewa	6.0	1320.6	50.8	6.2	11.4	7.4	10.6	2.6	11.0
Maduwanwewa	3.5	1149.6	15.0	7.8	22.7	24.2	19.5	9.2	2.2
Benthiswewa	2.0	520.3	23.3	-	25.3	28.8	18.5	0.8	3.2
Muwanpelessa	3.0	800.3	32.2	-	32.6	15.0	15.6	3.5	0.9
Angunakolapelessa	4.0	219.8	44.5	-	19.6	23.1	12.8	-	-
Kalawelgala	4.0	118.5	50.9	-	18.8	20.8	7.0	0.9	1.5

* Area at full supply level.

Although yields from seasonal tanks vary in different parts of the country, this extensive fish farming technique in seasonal tanks has a high potential for development due to its relatively high yields. It has been suggested that these tanks could be more effectively managed by cooperatives formed for each reservoir, and that harvesting could be staggered to prevent the flooding of the market over a very short period and thus obtain better prices for the fish. Staggered or selected harvesting will also mean that only the bigger fish are harvested while the slower growing individuals are allowed to grow further and sold upon reaching bigger sizes (De Silva, 1988a).

In small reservoirs of China, integration of the development of the fishery with that in the catchment and the low-lying area has been successfully practised (Lu and Zhen, in press). This method, with appropriate modifications to suit the local conditions, could be adopted for fishery development in seasonal tanks in Sri Lanka.

3.2 Cage Culture

Experiments on the culture of fish in cages have been conducted in some reservoirs. According to Muthukumarana and Weerakoon (1988), preliminary trials on cage culture using Indian and Chinese carps and *O. niloticus*, indicated that *O. niloticus* was the most suitable species because of its fast growth, good reaction to supplementary feed, and resistance to diseases under stressful conditions. On the other hand, the poor growth of Chinese and Indian carps in cages was attributed to low plankton productivity, the small initial size of fingerlings, the inadequacy of supplemental feeds, and the high incidence of disease (Muthukumarana and Weerakoon, 1988). These same trials have also shown that it is economically feasible to culture *O. niloticus* in cages at a stocking density of 200 fish/cu m provided a two-stage culture process is used. This type of culture system has produced 3,500-4,000 kg of fish per year from nine net cages measuring five cu m each. However, as the initial capital investment required is high, it is necessary to provide subsidies to the farmers (Muthukumarana and Weerakoon, 1988).

3.3 Fishpond Culture

Until 1990, the Ministry of Fisheries provided subsidy in the form of cash grants to meet part of the cost of pond construction. Data from 46 ponds in different parts of the country show that yields ranged from 200-5,200 kg/ha/culture period ranging from 6-13 months (Chakrabarty, 1983). The species cultured were bighead carp, silver carp, grass carp, common carp, *catla, rohu, mrigal, Chanos chanos, L. dussumieri*, and *O. niloticus* (Chakrabarty, 1983).

Recently, some settlers in the "Mahaweli Development Area" commenced the culture of *Macrobrachium* spp. in ponds using postlarvae provided by MOF. The culture of *M. rosenbergii* stocked at three pcs/sq m in 500-sq m ponds yielded a total harvest of 77 kg consisting of two size groups (100g and 53 g mean weight) valued at Rs. 11,875 (or US$296 at $\pm$USD1 = Rs. 40) after 25 weeks of culture (Hettiarachchi and

Kularatne, Kularatne, 1988). On the basis of this culture trial, Hettiarachchi and Kularatne (1988) performed a cost-and-return analysis of *M. rosenbergii* culture and showed that it would be a profitable culture practice (Table 5).

Table 5
Cost-and-return analysis, pond culture of Macrobrachium rosenbergii
(extrapolated to 1000 sq m assuming two crops are raised annually)
(Adopted from Hettiarachchi and Kularatne, 1988)

COSTS		
Pond construction, Rs. 25,000.00 depreciated over 25 yrs		Rs. 1,000.00
Nets for covering the pond and harvesting, etc., Rs. 8,000.00 depreciated over 4 yrs.		Rs. 2,000.00
Postlarvae, 6,000 pcs. @ Rs. 0.50/pc		Rs. 3,000.00
Feeds: Chick booster, 50kg @ Rs. 8.80/kg		Rs. 440.00
Prepared feeds, 1,000 kg @ Rs. 6.16/kg		Rs. 6,160.00
Labor: for harvesting, 10 man-days @ Rs. 75/man-day		Rs. 750.00
	Sub-total	Rs.13,350.00
Miscellaneous, 10% of sub-total		Rs. 1,335.00
	Total	Rs.14,685.00
RETURNS		
Sales: 180 kg of size group with mean weight of 100 g @ Rs. 175/kg		Rs.31,500.00
128 kg of size group with mean weight of 53 g @ Rs. 125/kg		Rs.16,000.00
	Total	Rs.47,500.00
Net profit		Rs.32,815.00
Profit per month:		Rs. 2,734.58

4. CAPTURE FISHERY MANAGEMENT

4.1 Management of the Capture Fishery in Perennial Reservoirs

The present regulations for the capture fishery management in reservoirs of Sri Lanka do not seem to have a scientific basis. For example, the mechanization of fishing crafts is not allowed and seine nets cannot be operated in reservoirs. Also, while the minimum permissible mesh size for the gillnet fishery is 7.5 cm, gillnet selectivity studies in Sri Lankan reservoirs (Amarasinghe, 1988b; De Silva and Sirisena, 1987) indicate that the mesh size corresponding to the mean size of *O. mossambicus* acceptable to consumers (about 24 cm) is about 10 cm. This is corroborated by findings from some Sri Lankan reservoirs (e.g., Parakrama Samundra) that to prevent overexploitation of *O. mossambicus* (which accounts for over 70 per cent of total landings), the mean landed size should be maintained above 20 cm for optimum yields (Amarasinghe, 1988a; Amarasinghe *et al.*, 1989). In Pimburettawa reservoir where gillnets with mesh sizes bigger than 10 cm are used, the yield-per-recruit analysis did not give any evidence of overexploitation of *O. mossambicus* (Amarasinghe, 1987). Based on the foregoing, it appears that a revision of existing mesh size regulations in the gillnet fishery in major reservoirs of the country, is desirable.

Based on an analysis of catch and effort data of the fisheries of Sri Lankan reservoirs, the maximum sustainable yield (MSY) has been estimated at 256 kg/ha/yr and optimal fishing effort per unit area (i.e., optimal fishing intensity) at 3.2 boats/sq km (De Silva *et al.*, 1991). The estimated MSY is lower than the present average yield of 283-307 kg/ha/yr of the reservoir fishery of the country where average effort per unit area (i.e., fishing intensity) is about 3.1 boats/sq km (De Silva, 1988a). When the individual reservoirs are considered separately, the fisheries of most reservoirs appear to be exploited at a sub-optimal level (Fig. 1). However, when all the reservoirs are considered as a single unit, rather than separately, it appears that the fishery was leaning towards overexploitation in 1984 (Fig. 2) (De Silva *et al.*, 1991). This has been shown by Amarasinghe (1988a) to be the case in some reservoirs where the fisheries are overexploited, resulting in decreased CPUE and reduced landing size of *O. mossambicus*.

With the use of a multiple regression technique similar to that employed by Marten (1979) to investigate the inshore fishery of Lake Victoria (East Africa), it has been shown that beach seining which is practised sporadically in some reservoirs, would lead to diminished returns through depletion of fish stocks (Amarasinghe and De Silva, in press).

Stocking of perennial reservoirs to enhance the natural recruitment is another management option for the reservoir fishery in the country. In Sri Lankan major reservoirs, attempts have been made to use Chinese and Indian major carps to augment reservoir production by regular stocking during the last three decades. Sreenivasan and Thayaparan (1983) advocate the stocking of major reservoirs with Indian carps; Sreenivasan (1989) is of the view that good stocking of Indian and Chinese carps in selected reservoirs will lead to establishment of the carp fishery. While Jayasekara (1989) reported that this effort has been intensified, the survey rates of Chinese and Indian carps in selected reservoirs have been generally low, ranging from 0.4 per cent for common carp to 36.5 per cent for catch in Pimburettewa (830 ha) (Table 6). Thus, while it has been claimed that the stocking-recapture fishery using *L. rohita* is economically feasible (Ilukkumbura, 1986), its poor percentage return makes this claim open to criticism (De Silva, 1989a). Hence, the stocking-recapture method does not look like a meaningful management strategy for augmenting fish yields in the major perennial reservoirs in Sri Lanka. The inconclusive results on the use of carps for fish stock enhancement in South Indian reservoirs (Sreenivasan, 1984, 1989) also seems to support this contention.

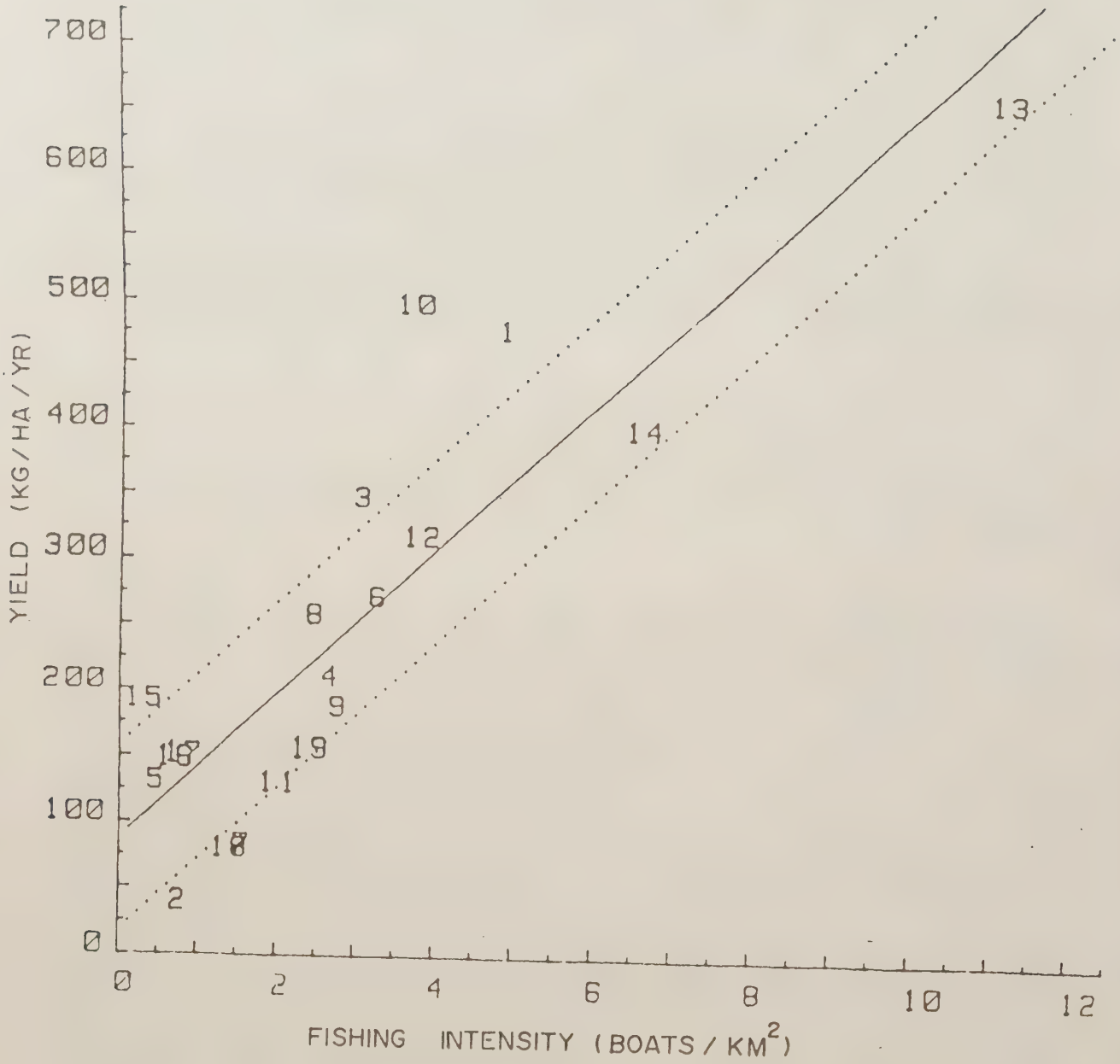

Fig. 1. Relationship of yield (kg/ha/yr) to fishing effort per unit area (number of boats/sq km) for the different reservoirs in Sri Lanka (adopted from De Silva *et al.*, 1991). (1 - Badagiriya; 2 - Huruluwewa; 3 - Kalawewa; 4 - Kaudulla; 5 - Lunugamwehera; 6 - Maduruoya; 7 - Mahakanadarawa; 8 - Mahawillachchiya; 9 - Minneriya; 10 - Nachchaduwa; 11 - Padaviya; 12 - Parakrama Samudra; 13 - Pimburettewa; 14 - Rajanganaya; 15 - Ridiyagama; 16 - Senanayaka Samudra; 17 - Udawalawe; 18 - Weerawila; 19 - Yodawewa.)

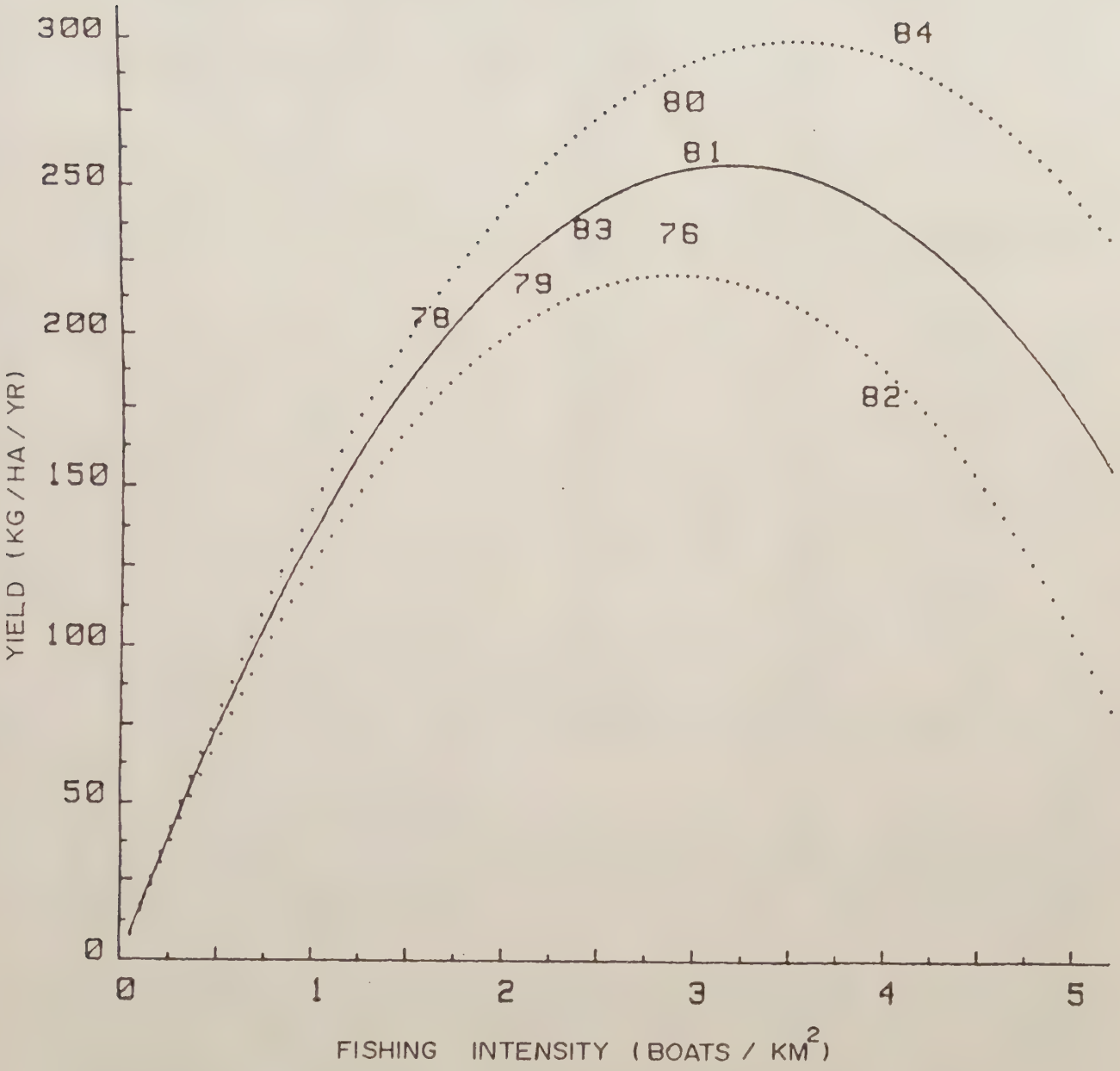

Fig. 2. The relationship of mean annual yield (kg/ha/yr) to fishing effort per unit area (boats/sq km) in the Sri Lankan reservoir fishery (adopted from De Silva *et al.*, 1991).

Table 6
Recovery of stocked carps in selected reservoirs of Sri Lanka (from Hettiarachchi, 1990)

Reservoir	Species	Total number stocked, 1983-1987	Total catch (mt) 1984-1988	Number of fish recovered	% recovery
Giritale	Bighead	365000	89.3	29800	8.2
(308 ha)	Common carp	11000	5.0	1700	15.5
	Mrigal	56000	12.9	4300	7.7
	Rohu	148000	38.5	12900	8.7
	Silver carp	25000	-	-	-
Kaudulla	Catla	4000	-	-	-
(2713 ha)	Common carp	4000	-	-	-
	Rohu	10000	-	-	-
Maduru Oya	Bighead	131000	3.5	1200	0.9
(2551 ha)	Common carp	24000	-	-	-
	Rohu	60000	-	-	-
Minneriya	Bighead	90000	72.6	24200	26.9
(2551 ha)	Mrigal	34000	10.6	3500	10.3
	Rohu	135000	58.2	19400	14.4
Parakrama	Bighead	64000	-	-	-
Samudra	Catla	10000	7.4	2500	25.0
(2262 ha)	Common carp	92000	-	-	-
	Rohu	304000	61.4	20500	6.7
Pimburettewa	Bighead	6000	-	-	-
(830 ha)	Catla	2000	2.2	730	36.5
	Common carp	72000	1.0	300	0.4
	Mrigal	128000	2.9	1000	6.2
	Rohu	34000	13.5	4500	13.2
	Silver carp	86000	36.6	12200	14.1

Note: The weight of an average fish harvested has been assumed to be 3 kg.

Empirical models have been used to predict fish yields in Sri Lankan reservoirs. Wijeyaratne and Amarasinghe (1987) observed fish yield to be correlated with the morpho-edaphic index or MEI (i.e., the ratio of electrical conductivity to mean depth of reservoir). However, De Silva (1985, 1988a) has shown that MEI is not significantly correlated to fish yields when several reservoirs scattered over the dry zone of the country are used. This perhaps suggests that the reservoirs may be categorized into a number of groups depending on several parameters which determine biological productivity of reservoirs, and that there is a necessity to classify reservoirs in the Asian region depending on a number of characteristics ranging from morphometry to biological productivity (De Silva, 1986b).

De Silva (1988a) found that in Sri Lanka, fish yields are related to reservoir surface area. Some evidence has also been found on the effect of water regime on fish yields in Sri Lankan reservoirs with fish yield being positively correlated with annual catchment inflow as described by the equation:

$$Y_t = 1.4449\ I_f + 217.6138 \quad (r = 0.83;\ p < 0.001)$$

where: Y_t = total yield in mt/yr and I_f = inflow in million cu m (Blay and Amarasinghe, in preparation). This provides an insight into the development of the inland fishery within constraints of other uses of reservoirs since the water regime of most reservoirs in Sri Lanka is controlled for irrigation purposes.

4.2 Development of a Subsidiary Fishery for Minor Cyprinids

Minor cyprinids are abundant in reservoirs of Sri Lanka (Fernando, 1967; Schiemer and Hofer, 1983) but remain unexploited due to the mesh size restriction (7.5 cm) in the gillnet fisheries in reservoirs which has been imposed by MOF to control the landing size of *O. mossambicus* and the extreme difficulty of fishing gears other than gillnets, due to the presence of submerged tree stumps in most reservoirs.

De Silva (1983) hypothesized that these minor cyprinids could be exploited without harming the existing *O. mossambicus* fishery since the latter exhibits a depth preference with size. On the basis of this hypothesis, experimental fishing trials were conducted in a number of reservoirs of Sri Lanka. The results indicated that four species of minor cyprinids abundant in the reservoir fish fauna (viz., *Amblypharyngodon melettinus, Barbus dorsalis, B. chola,* and *B. filamentosus*) could be exploited using 15-52 mm mesh gillnets without affecting the existing *O. mossambicus* fishery (Amarasinghe, 1985; De Silva and Sirisena, 1987; Sirisena and De Silva, 1989).

De Silva and Sirisena (1989), using the ratio of minor cyprinids and *O. mossambicus* caught in the commercial-scale trials, and the commercial catches of *O. mossambicus* in the reservoirs, estimated the potential yield of minor cyprinids to range from 35-2,191 kg/ha/yr with a mean of 907 kg/ha/yr, in six reservoirs of southern Sri Lanka (De Silva and Sirisena, 1989; De Silva, 1989a). The annual potential yield of minor cyprinids in Parakrama Samudra, estimated by comparing CPUE values of minor cyprinids with those in reservoirs of southern Sri Lanka, is about 632 kg/ha (Amarasinghe, 1990). In some reservoirs, the minor cyprinids are fished on a small scale and sold as dried fish, making this resource a potential source of income for fishermen (Amarasinghe, 1990).

The estimated potential yields of minor cyprinids (De Silva and Sirisena, 1989; Amarasinghe, 1990) are appreciably higher than the *O. mossambicus* yields in reservoirs. Hence, the establishment of a subsidiary gillnet fishery for minor cyprinids in which two groups of fishermen co-exist, is an additional approach towards achieving high fish yields in reservoirs (De Silva, 1989b). However, as indicated by Amarasinghe (1990), these estimated potential yields of minor cyprinids may not be sustained once the fish populations come into equilibrium with the level of exploitation. It should also be noted that the potential yields of minor cyprinids could have been overestimated since they were computed by comparing minor cyprinid catches in the survey with the catches from the stabilized *O. mossambicus* fishery. However, fish yields in reservoirs could undoubtedly be increased by introducing a small-mesh gillnet fishery for the minor cyprinids.

De Silva and Sirisena (1989) stated that once a new subsidiary fishery is introduced, it would be necessary to monitor the fishery very closely as the biological effects of introducing such a fishery on the cyprinid stocks as well as other stocks, are not known. In fact, De Silva (1988c), in a memorandum to the Ministry of Fisheries of Sri Lanka, recommended that the small-mesh gillnet fishery for minor cyprinids should be initially restricted to a few reservoirs and only for six months, and that an evaluation should be made at the end of the period for further amplification and extension of the fishery.

4. CONSTRAINTS TO DEVELOPMENT

The major constraints to the development of the inland fishery in Sri Lanka seem to be those associated with religious and cultural factors. Recently, due to pressure from Buddhist religious groups, the Sri Lankan Government decided to stop state support for the development of the inland fishery in the country despite evidence found in stone inscriptions that fishing in reservoirs and other inland waters has been practised in Sri Lanka since time immemorial when Buddhist traditions were very strictly observed and taxes were charged for fishing rights in reservoirs (Siriweera, 1986). No restrictions have been imposed on the private sector and NGOs, however, and the Ministry of Fisheries still continues extension work pertaining to the capture fisheries in reservoirs (e.g., imposing fishery regulations, organizing fisheries cooperative societies, welfare activities, etc.). Also, the National Aquatic Resources Agency (NARA), the research arm of the MOF, is expected to continue research on inland fisheries and aquaculture, in order to provide technical knowhow to the private sector.

Despite these contraints, the inland fishermen in the dry zone of Sri Lanka are exclusively engaged in fishing in major reservoirs due to the vital importance of the reservoir fishery as a cheap animal protein source for rural communities. It is therefore necessary to involve the fishermen in the implementation of management strategies to optimize fish yields in major reservoirs through fisheries cooperative societies formed by the "organized" fishermen.

The agricultural farmers in most parts of the country have also expressed their willingness to get involved in freshwater aquaculture as a supplementary source of income. In the agriculture sector, farmers can enter into agreements with certain private enterprises for the cultivation of crops for export and/or as raw materials for the products of these enterprises (e.g., tobacco, gherkin, asparagus), or poultry-raising under a buy-back scheme, where the farmers are provided with the inputs and technical advice and their produce is purchased by entrepreneurs at the end of the growing period. A similar approach could be adopted to develop aquaculture in seasonal tanks and ponds, with the private sector possibly participating in the pond culture of *Macrobrachium* which usually sells at prices much higher than other freshwater fish.

5. CONCLUSION

The reservoir capture fishery of Sri Lanka, which is almost entirely based on the exotic cichlid species, is one of the most productive in the Region with yields of over 300 kg/ha/yr. While the introduction of cichlids into Sri Lankan freshwaters has not produced any apparent harmful influences on the indigenous flora and fauna, effective management strategies are nonetheless required for the further sustainable development of the fishery in the country's inland waters, particularly in its large, perennial reservoirs.

Inland fish culture, especially in seasonal tanks, has been shown to have a high potential for development, especially in the remote areas where it can provide livelihood/additional sources of income to the rural communities.

Development strategies and management plans for inland capture and culture fisheries should be formulated within the framework of integrated rural development, and implemented with the active involvement and participation of the local communities to ensure their success. It has been shown in many places that when the local people's aspirations are considered and when they are truly and fully involved, management plans are effectively and efficiently executed. It is time for research and development efforts to veer away from the conventional resources-oriented approaches and move towards the integrated approach that takes into account both the resources as well as the communities that utilize the resources. The importance of such an approach in the management of artisanal fisheries in the Asian region can no longer be overlooked (Aguero and Lockwood, 1986).

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INLAND CAPTURE FISHERIES IN THAILAND

by

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1. INTRODUCTION

Thailand is an agricultural country with a land area of 513,100 sq km, of which about 45 per cent is used for cultivation. The rest is mainly forest or savannah. It has a population of about 55 million and a density of 107 persons/sq km. Approximately 70 per cent of the population live in the rural areas in the north and northeast regions. Fishing in freshwaters is only for household consumption, except in the floodplain areas in the central region where fishing used to be undertaken as a commercial activity. Since these areas no longer exist at present, commercial fishing has shifted to reservoirs and river systems.

2. INLAND FISHERY RESOURCES

Thailand has abundant inland water resources. It has 47 major rivers and canals with a total area of about 120,000 ha, excluding the Maeklong river which shares a common boundary of about 800 km with Lao in the north and northeast of Thailand. Some river systems, such as the Chaophraya and Maeklong, are regulated for hydroelectric power generation, irrigation, and flood control. Since the construction of dams across these rivers, the major fisheries have shifted from the floodplains to the newly created reservoirs. In some non-regulated river systems in the north and northeast, the intensity of fishing depends on the floods but fishing is not as successful as compared to that in the central plain.

In addition to its rivers, Thailand has about 8,000 natural lakes and swamps covering a total surface area of 300,000 ha (Anon., 1956). It also has 425,000 ha of reservoirs, 16,330 ha of village ponds, and 143,300 ha of public waters (Table 1). These natural lakes vary greatly in size from less than one ha to over 10,000 ha. The major natural lakes are Bung Borapet (13,000 ha) in the central plain, Nong Harn (12,500 ha) in the northeast, and Kawn Phyao (2,100 ha) in the north, excluding the 96,000-ha Songkhla Lake which is classified as a brackishwater lake. Most natural lakes are shallow with depths of a few meters due to the accumulation of silt and the heavy infestation of aquatic weeds. Their actual surface areas change drastically between the dry and wet seasons. Settlements and cultivation have encroached on most drawdown areas. As a result, the total surface area of these lakes may be much smaller at present as compared to earlier estimates.

Table 1
Number and areas of water impoundments in Thailand, 1986–1988.

Type of water impoundment	1986		1987		1988	
	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Reservoirs	1,498	381,430	1,598	423,000	1,745	425,500
Village ponds	2,295	14,167	2,397	15,700	3,147	16,330
Irrigation tanks and other impoundments						
Public waters	9,964	139,000	10,185	-	10,859	143,000

Source: Department of Fisheries (DOF).

In 1983, there were 14 major reservoirs in Thailand with a total area of 218,459 ha and individual surface areas ranging from 1,200 ha to 41,000 ha (Baluyut, 1983). In addition, there are small and medium-sized reservoirs which have steadily increased in number - from 1,498 in 1981 to 1,745 in 1988 (Table 1), mainly as a result of Cabinet approval of a number of rural development projects. The newly created reservoirs, however, are only small and medium in size with areas ranging from 10-200 ha. No major reservoir of over 1,000 ha has been constructed due to opposition received from conservationists and environmental protection lobbyists, but two projects - at Nam Moon and Nam Chi - are presently being considered for implementation. While new reservoirs are used mainly for water storage for domestic supply and irrigation, they could also be used for fisheries with the application of appropriate management techniques.

Village ponds are small reservoirs constructed for fish production. They are so designed as to have a nursery pond adjacent to the main pond to enable easy stocking of fingerlings and are provided with suitable inlets and spillways for ease of operation. As of 1988, there were 3,174 village ponds distributed throughout the country with a total surface area of about 16,300 ha (Table 1); an additional 300 ponds are expected to be completed each year. Responsibility over the village ponds belongs to the Department of Fisheries (DOF).

3. FISH SPECIES

Of the more than 150 species of fish recorded in catches from inland waters, about 20 species are economically important. The following families dominate the catch: Cyprinidae, Clupeidae, Ophicephalidae (murrel), and Siluridae (catfish).

Carps are the most numerous fish and include: *Puntius gonionotus*, *Puntioplites proctosyzron*, *Cirrhinus jullieni*, *Osteocheilus hasselti*, *Labiobarbus lineatus*, *Morulius chrysophekadion*, etc. Only two species of murrel contribute a major part of the catch, namely: *Channa striatus* and *C. micropeltes*, both of which are highly preferred by Thais. The following species belong to Siluridae and Clariidae: *Clarias batrachus*, *C. macrocephalus*, *Pangasius sutchi*, *P. larnoudii*, *P. siamensis*, *Kryptopterus apogon*, and *Ompok bimaculatus*. *Corica siamensis* is the only representative of Clupeidae that contributes considerable amounts to the catch, particularly from large reservoirs.

4. FISHERIES PRODUCTION

The total annual fisheries production in Thailand ranged from 1.23 million mt in 1979 to about 2.8 million mt in 1987, with a generally upward trend observed in the last decade (Table 2). Of the total production from capture and culture fisheries over the period 1977-1988, marine fisheries contributed an average of 1.96 million mt or 87 per cent. In comparison, inland capture fisheries accounted for a small 4.1 per cent of total fish production, on the average, over the same period (Table 2).

Table 2
Fisheries production in Thailand (in '000 mt), 1977–1988.

Year	Total Production (mt)	Capture				Culture			
		Marine		Inland		Coastal		Freshwater	
		Volume (mt)	% of total	Volume (mt)	% of total	Volume (mt)	% of total	Volume (mt)	% of total
1977	2189.9	2064.4	94.2	89.2	0.04	3.2	0.001	33.1	1.5
1978	2099.3	1947.7	92.7	102.1	4.8	10.1	0.48	39.4	1.8
1979	1226.3	1082.3	55.6	103.7	5.3	10.9	0.56	29.4	1.5
1980	1783.9	1587.9	80.4	101.4	5.1	60.1	3.04	34.5	1.7
1981	1989.0	1756.9	88.3	116.5	5.8	67.5	3.4	48.1	2.4
1982	2120.1	1949.7	91.9	87.7	4.1	36.9	1.7	45.8	2.1
1983	2255.4	2055.2	91.1	108.4	4.8	44.8	1.9	47.0	2.1
1984	2134.8	1911.5	89.5	111.4	5.2	61.5	2.8	50.4	2.4
1985	2225.4	1997.2	89.7	92.4	4.2	60.6	2.7	75.2	3.4
1986	2536.3	2309.5	91.0	98.4	3.9	39.1	1.54	89.3	3.5
1987	2779.1	2540.0	91.4	87.4	3.1	61.9	2.2	89.8	3.2
1988	2629.7	2337.2	88.8	81.5	3.1	108.9	4.1	102.1	3.9
Average	2239.8	1961.6	87.0	98.3	4.1	47.1	2.0	57.01	2.54

Source: Department of Fisheries , Thailand, 1988.

Of the total freshwater fisheries production, roughly 50 per cent comes from fish capture in natural waters and reservoirs and the other half from aquaculture. Of the catch from inland capture fisheries, some 41,570 mt were taken from rivers and canals; 20,640 mt from reservoirs; 17,087 mt from public waters; and 2,178 mt from village ponds. The total fish production does not include the portion of the catch that is consumed by the fishermen and their families. This volume could be substantial, as in the case of the Ubolratana reservoir where it has been estimated to be 460 mt/yr or 25 per cent of annual catch (Pawaputanon, 1987). This implies that the actual total catch figures could be higher than reflected above.

In terms of species composition of the catches from the country's lakes and reservoirs, information collected from five large reservoirs in 1988 shows that the species present in these man-made lakes belong to four major groups, namely: carps, murrels, catfishes, and clupeids, with the dominant group varying from one reservoir to the other. As shown in Table 3, the carps comprise the most important group in Ubolratana and Kangkrachan reservoirs at 63.2 and 90.1 per cent of total production, respectively. The clupeids are dominant in Sirinthorn and Sirikit reservoirs, while the murrels predominate in catches in Chiewlan reservoir.

Table 3
Yields (in '000 mt) from Thai reservoirs in 1988.

Reservoir	Carp	Murrel	Catfish	Clupeid	Others	Total
Sirinthorn	90.2	12.1	35.5	436.3	171.6	745.7
	(12.1)	(1.6)	(4.7)	(58.5)	(23.1)	
Ubolratana	1086.9	14.1	44.8	320.0	252.2	1718
	(63.2)	(0.8)	(2.6)	(18.6)	(14.7)	
Chiewlan	95.6	132.1	93.1	15.5	109.2	445.5
	(21.4)	(29.6)	(20.9)	(3.5)	(24.5)	
Sirikit	82.1	4.2	105.9	177.8	58.8	428.8
	(19.1)	(1.0)	(24.7)	(41.5)	(13.7)	
Kangkrachan	113.2	4.1	8.3	n.a.	-	125.6
	(90.1)	(3.3)	(6.6)	(-)	-	

Note: Figures in parentheses indicate percentage of total production from each reservoir.

5. FISHERY MANAGEMENT

Several fishery management techniques have been introduced in Thailand to optimize fish yields and conserve some fish species. Among these, the most effective and suitable techniques include fish stocking and regulated fishing in terms of fishing gears and fishing seasons.

5.1 Fish Stocking

Stocking programs have been carried out in Thailand as early as 1950 when *Trichogaster pectoralis* and *Oreochromis mossambicus* were stocked into natural swamps (Bhukaswan, 1983). Later, several local and exotic species have been introduced into lakes, swamps, reservoirs, and river systems throughout the country. The fish species that have been introduced into these waterbodies are fast-growing and occupy ecological niches not used by existing species, e.g., *Cyprinus carpio, Labeo rohita, Oreochromis niloticus,* and Chinese carps.

At present, the stocking programs have shifted to using local species - either for the improvement of fish yields in reservoirs (e.g., *Puntius gonionotus*) or for conservation or repopulation of economically important species whose populations have been observed to be declining as a result of intensive fishing and altered habitats (e.g., *Pangasius sutchi, Pangasianodon gigas, Probarbus jullieni, Notopterus chitala, and Osphronemus gouramy*).

Over 100 million fingerlings of various fish species are introduced into the reservoirs each year. Their recovery rate has been evaluated to be lower than one per cent in large reservoirs (Pawaputanon, 1986) and the degree of stocking success varies from one reservoir to another although the recovery rate with bigger-sized fingerlings seems to be better than with fry or small-sized fingerlings.

5.2 Regulated Fishing

Fishing in inland waters is closely regulated by DOF by way of restrictions on fishing gear, fishing seasons, and fishing areas.

Traditional fishing gears like gill nets, cast nets, longline hooks, and lift nets are not regulated since they cause no damage to the fisheries. However, those that are very effective and may cause damage to fish populations are prohibited, such as trawling with motor boat, purse seine, and surrounding or blocking nets. Electrofishing, poisoning, and the use of explosives are banned.

To protect the newly hatched or young fish and allow them to grow to bigger sizes in the nursery grounds, fishing is restricted during the spawning season (May-September) with the duration of restriction varying with location and other factors.

6. FISHERIES DEVELOPMENT

A number of programs have been formulated and are being implemented for the purpose of improving the performance of the inland fisheries, both capture and culture. These include the following:

(i) Establishment of the National Aquaculture Genetic Institute in 1989 with assistance from the International Development Research Center (IDRC) of Canada and the European Community (EC);

(ii) Establishment of village hatcheries which are operated by volunteer groups primarily to supply the fingerlings required by the village ponds and secondarily to sell fingerlings to nearby villages;

(iii) Establishment of Fishery Law Enforcement Units for Freshwaters in various parts of the country, especially where fishing is intensive, to ensure that fishing regulations are enforced; and

(iv) Implementation of the Repopulation of Thai Fishes Project involving activities meant to conserve and improve the population of about 50 economically valuable local species including collection of broodstock from natural waters, artificial breeding, fry rearing, and stocking in open waters.

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PART TWO

PAPERS CONTRIBUTED TO THE WORKSHOP ON TILAPIA IN CAPTURE AND CULTURE-ENHANCED FISHERIES IN THE INDO-PACIFIC FISHERY COMMISSION COUNTRIES BOGOR, INDONESIA, 27-29 JUNE 1991

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TILAPIAS IN CAPTURE AND CULTURE-ENHANCED[1] FISHERIES OF THE INDO-PACIFIC

by

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Since the introduction of tilapias into many countries of Asia and the Pacific in the middle of this century, there has been an ongoing discussion on the appropriateness of these fish for the Indo-Pacific region. The introduction of exotic tilapias (there are three species indigenous to Sri Lanka, but of little regional significance) has raised high expectations for this fish, but it has also led to several concerns. While tilapias have been viewed as a highly beneficial fish for aquaculture, the benefits have been less clear in capture fisheries especially when compared with the large group of the indigenous Asian cyprinids. There has also been concern regarding their impact on local fish stocks in open waters.

Two groups of fish are now of primary importance in the inland fisheries of Asia and the Pacific: cyprinids and tilapias. While the cyprinids are indigenous west of the Wallace's line (i.e., in most of Asia), the tilapias, with a few exceptions, are exotic throughout Asia and the Pacific. China has 417 species of cyprinids and Thailand, over 250 indigenous species; therefore, in both countries, cyprinids may be expected to highly dominate inland capture fisheries. A workshop on the use of cyprinids in the fisheries management of larger inland waterbodies of the Indo-Pacific, organized by FAO in Kathmandu in 1988 (FAO, 1988), highlighted the significance of cyprinids for the Region. It also pointed out differences in cyprinid significance among the various countries of the Region and also among different areas within each country.

Tilapias, since their introduction into Asia in the 1950s, became fully established in numerous inland waterbodies and in some coastal brackish and fully saline lagoons, and became an important part of freshwater aquaculture. In 1988, some 267,329 mt of tilapias were reported captured, and 179,667 mt produced in aquaculture in the countries of Asia (Table 1). *Oreochromis mossambicus* has been the dominant species in many capture fisheries although in those countries where tilapias are stocked intentionally (e.g., Thailand), *O. niloticus* is the dominant species.

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[1]Culture-enhanced implies that some fishery resource already exists. However, by periodic stocking of one or more of the indigenous species or a non-indigenous species, the catch is augmented.

Table 1
Tilapia production (mt) from capture fisheries and aquaculture in Asia, 1988 (from FAO, 1990a, 1990b)

Species	Production (mt) from	
	Capture Fisheries	Aquaculture
O. mossambicus	89 (Brunei)	
	1830 (Hongkong)	476 (Thailand)
	36580 (Indonesia)	25228 (Indonesia)
	2350 (Malaysia)	2350 (Malaysia)
Total	40849	28054
O. niloticus	10750 (Indonesia)	10750 (Indonesia)
	17370 (Thailand)	16980 (Thailand)
		26719 (Philippines)
		39000 (China)
		300 (Saudi Arabia)
Total	28120	93749
O. spilurus		28 (Saudi Arabia)
Tilapias n.i.	4025 (Israel)	4536 (Israel)
	4760 (Japan)	4760 (Japan)
	996 (Malaysia)	241 (Malaysia)
	95006 (Philippines)	48327 (Philippines)
	38012 (Sri Lanka)	
	55561	
Total	198360	57864
Grand Total	267329	179667

Note: Some countries do not differentiate between capture fisheries and aquaculture in their statistics. Therefore, there is an obvious overlap in these figures and the total for capture fisheries and aquaculture must be lower than that presented in the table.

A comparison of the total production of cichlids and cyprinids in capture fisheries and aquaculture in countries of Asia shows that while cyprinids are highly dominant (largely due to the high production in China), tilapia production in aquaculture and in capture fisheries outside China is about two-thirds that of cyprinids (Table 2).

Table 2
Tilapia and cyprinid production (mt) from capture fisheries and aquaculture in Asia, 1988 (from FAO, 1990a, 1990b)

Source	Production (mt)	
	Tilapias	Cyprinids
ASIA (with China)		
Capture Fisheries	306,329	4,112,186
Aquaculture	181,985	4,080,259
China		
Capture Fisheries	39,000	3,740,800
Aquaculture	39,000	3,858,500
ASIA (without China)		
Capture Fisheries	267,329	371,386
Aquaculture	142,985	221,759

Note: These data differ from those in Table 1 as statistical data reporting was not yet standardized.

Production in China is based on the regular stocking of hatchery-produced fingerlings into reservoirs and smaller waterbodies and on their efficient harvesting; for this reason, almost identical figures for aquaculture and capture fisheries are presented in the two statistical yearbooks (FAO, 1990a, 1990b). The difference is due to the absence in the capture fisheries data, of the production of 117,000 mt of black carp.

Among the countries in the Region, it is in Sri Lanka where the tilapias have been most successful, with production reaching 38,000 mt in 1988. The average production of perennial reservoirs in Sri Lanka is estimated to be 283-307 kg/ha/yr (De Silva, 1988). In almost all the major reservoirs, the predominant tilapia species is *O. mossambicus*, which usually represents 60-100 per cent of the catch. In some reservoirs, however, *O. mossambicus* is being gradually replaced by *O. niloticus* which has also established self-reproducing stocks. In reservoirs with macrovegetation, the introduced *Tilapia rendalli* is also doing well. It therefore appears that with established self-reproducing stocks, the species is there to stay, with minimum management requirements and maximum benefits to the country where it is estimated that about 25 per cent of the human population is dependent on freshwater fish for their animal protein requirements.

In the Philippines, the production of tilapia from both capture fisheries and aquaculture registered a sevenfold increase from 6,122 mt in 1979 to 43,203 mt in 1984. In 1989, production reached 101,642 mt, equivalent to a 135 per cent increase over the 1984 level. Of this volume, about 81,630 mt, or 80 per cent, came from aquaculture (freshwater fishponds, fishpens, and fish cages) and the rest from municipal capture fisheries. The percentage contribution of fish cage culture to total production has decreased over the past several years with the declining importance of Laguna de Bay as a fisheries resource. It could be noted that since the peak of the expansion of the fishpen and fish cage industry in Laguna de Bay in the early 1980s, a host of environmental problems, some of them attributable to the negative impacts of the industry itself, aquaculture production in the lake has dropped significantly. Meanwhile, the area devoted to freshwater fishponds increased and tilapia production from this source has increased. Nonetheless, both *O. niloticus* and *O. mossambicus* continue to be present in Laguna de Bay where around 450 ha of fish cages were reported in 1990. In other freshwater lakes like the shallow Lake Buluan and the deep Lake Lanao, where the occurrence of tilapias had been earlier recorded (Baluyut, 1983), the tilapias still occur in the fish catches.

In India, the tilapias are not included in official statistics (and therefore, are also absent from Tables 1 and 2). It is known, however, that *O. mossambicus* is contributing to fish catches in a number of reservoirs in southern India, e.g., Amaravathy, Uppar, and Mettur reservoirs (Sreenivasan, 1989).

In Papua New Guinea, the inadvertent introduction of *O. mossambicus* resulted in a short boom in the capture fisheries of the Sepik river floodplain system, although this was interrupted, in the late 1970s, by an invasion of the aquatic weed *Salvinia molesta*, which made fishing virtually impossible. After the biological control of *Salvinia*, the tilapia fishery has recovered and together with common carp (another exotic species not intentionally introduced), *O. mossambicus* now represents much of the catch, especially in the lower Sepik river system. Tilapia production is expected to increase further with the recent introduction of *Tilapia rendalli* into this extensive river system.

In Thailand, *O. niloticus* stocked in a number of reservoirs has successfully established itself and is now a regular component of the catch, together with seven exotic carp species (Bhukaswan, 1989).

The tilapias are not always appreciated. In northern India and in Bangladesh, for example, demand for the fish is often poor and the prices, consequently low. According to Saxena (1988), the future success of tilapia in India would seem to depend on the selection of the appropriate culture technology and on studies of interrelationships of tilapia with existing species and control of excessive reproduction by predators. The small size of the fish as a result of stunting is an obstacle to marketing since larger size freshwater fish are usually preferred.

In Bangladesh, tilapia is still considered a new fish species, and as such, demand for it is low. This shows that for socio-cultural reasons, it can take time before a new species is accepted and used as a new protein source (tilapias were introduced into Bangladesh in 1954).

Resistance to tilapia is also evident in countries where its control, after the initial introduction, has been extremely difficult, as in Nauru, where *O. mossambicus* has adversely affected the culture of milkfish (*Chanos chanos*) in ponds and lagoons (Ranoemihardjo, 1981). In Hawaii, *O. mossambicus* was introduced in all the major islands in the early 1950s for use as skipjack bait. It is now well adapted to the marine environment of Fanning Atoll and, according to the atoll fishermen, has caused a decrease in mullet, bonefish, and milkfish (Lobel, 1980). In Australia, tilapia is an unwanted fish believed to represent a potential threat to the native species. This notwithstanding, and in view of the fact that the *O. mossambicus* populations present in the country are relatively pure and have good growth rates, it has been suggested that they could serve as broodstock to re-introduce pure strains into countries in Asia where catches have been declining because of the effects of inbreeding, hybridization, and overfishing (Bluhdorn *et al.*, 1990).

In summary, the tilapias have thus become a major contributor to the increased fish production from capture fisheries as well as from aquaculture in numerous waterbodies in Asia and the Pacific. With the introduction of cage and pen fisheries into reservoirs and lakes, such as in the Philippines and Indonesia, high yields have been achieved at a reasonable cost. At the moment, the improvement of tilapia fish stocks through genetic selection is a priority both for capture and culture fisheries.

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TILAPIA IN AUSTRALIA AND SMALL PACIFIC ISLANDS: UNWANTED PEST OR UNAPPRECIATED RESOURCE?[1]

by

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1. INTRODUCTION

Geographically and, increasingly, politically and economically, Australia is part of the Indo-Pacific region. Many neighboring countries have adopted the group of cichlid fishes generally referred to as tilapias (genera: *Tilapia, Sarotherodon, and Oreochromis*) as an important and expanding source of food supply, employment, and economic benefits (Costa-Pierce *et al.*, 1988; Smith and Pullin, 1984; Kuo, 1984; Smith *et al.*, 1985). Tilapias are employed in the full range of freshwater fishing activities, from artisanal and subsistence capture fisheries (Chandrasoma, 1986; Coates, 1985) through low technology extensive culture (Edwards and Kaewpaitoon, 1984; PCARRD, 1985) to high-technology mono- and polyculture enterprises (Bimbao and Smith, 1988). Worldwide, a large array of tilapiine species are the subject of extensive research and intensive culture (Balarin and Hatton, 1979) to the point that three international symposia on the subject of tilapia aquaculture have been held up to now. Given opportunities similar to the rest of the Region, why has Australia come up with an opposite reaction to that of other countries; that is, the complete prohibition of tilapia species?

The aim of this paper is to examine the depth and range of questions and attitudes which went into the formulation of this policy and thus make Australia's stand on tilapia a little more understandable.

Figure 1 illustrates a model which represents the information flows involved in the consideration of such a problem.

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[1]The opinions expressed in this work are those of the authors and, unless specifically stated otherwise, do not necessarily reflect those of any government department, statutory body, organization, or other individual.

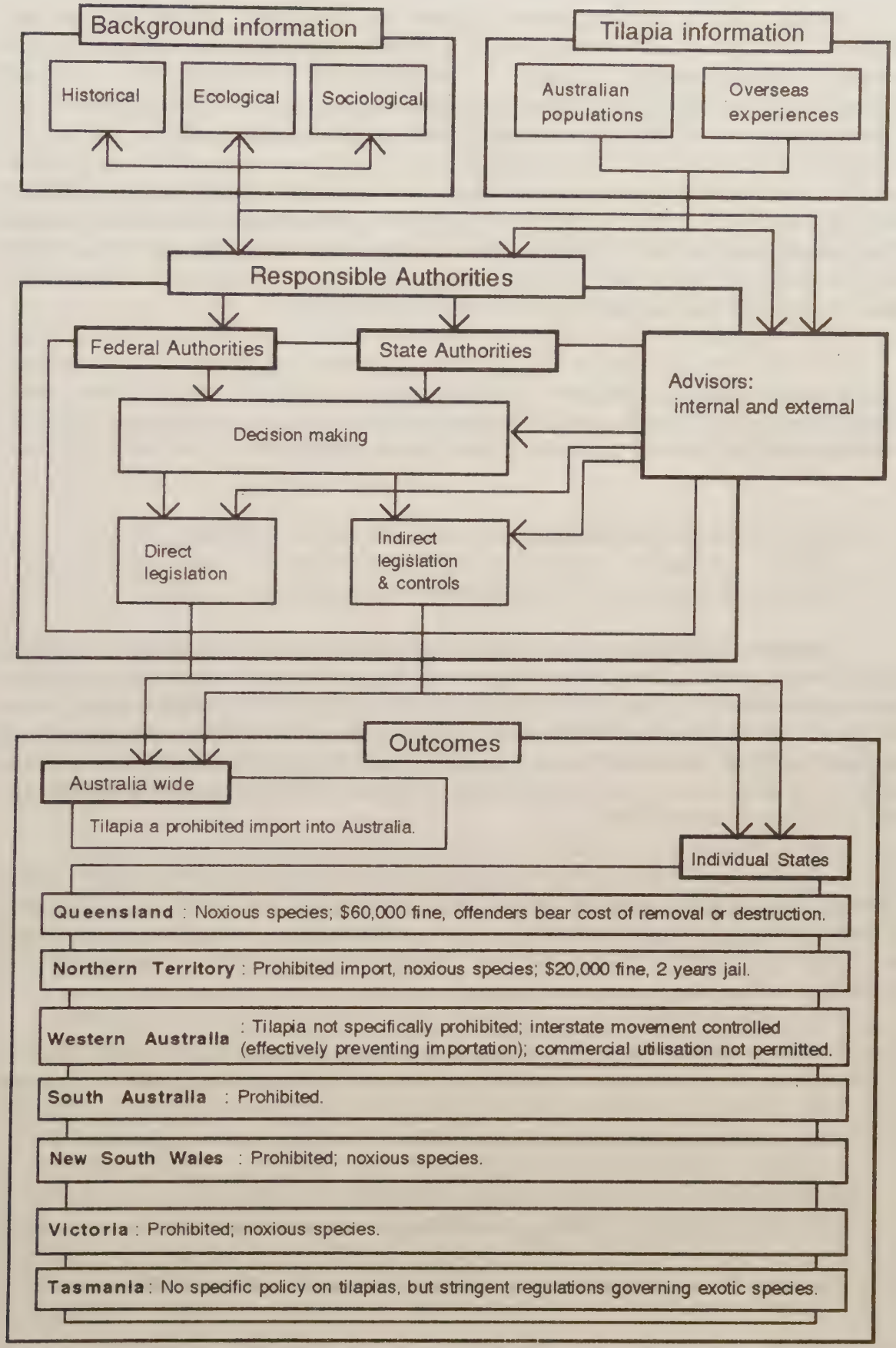
Background information
Historical
Ecological
Sociological
Tilapia information
Australian populations
Overseas experiences
Responsible Authorities
Federal Authorities
State Authorities
Advisors: internal and external
Decision making
Direct legislation
Indirect legislation & controls
Outcomes
Australia wide
Tilapia a prohibited import into Australia.
Individual States
Queensland : Noxious species; $60,000 fine, offenders bear cost of removal or destruction.
Northern Territory : Prohibited import, noxious species; $20,000 fine, 2 years jail.
Western Australia : Tilapia not specifically prohibited; interstate movement controlled (effectively preventing importation); commercial utilisation not permitted.
South Australia : Prohibited.
New South Wales : Prohibited; noxious species.
Victoria : Prohibited; noxious species.
Tasmania : No specific policy on tilapias, but stringent regulations governing exotic species.

Fig. 1. A conceptual model illustrating the steps involved in examining the issues and deciding the status of the exotic cichlid genera, *Oreochromis, Tilapia*, and *Sarotherodon* in Australia.

Initially, three major background aspects are examined. These are labelled: Historical; Ecological; and Sociological. All have input into, or effects on, the subsequent decision-making process. Following this, Australian and overseas experiences are examined, with reference to the species *Oreochromis mossambicus* and the feral populations of this species which presently exist in this country.

The opinions, attitudes, and findings derived from the above two sections are inputs into the next section labelled Responsible Authorities. Here, the various authorities with legislative responsibility for management of aquatic resources in this country consider relevant questions and advice. The outputs from this stage of the model represent the considered decisions of these authorities.

The final section of the model lists the Authorities' legislative and less formal methods of enforcement and control. Australia's present, nationwide policy with regard to tilapia emerges both as the combined result of these separate decisions and collective decision-making by all state authorities under federal auspices.

2. THE CONCEPTUAL MODEL: BACKGROUND INFORMATION

2.1 Historical Background: Two Centuries of Introductions

The settlement of the Australian continent by a developed European nation just over 200 years ago led to a rapid and almost total importation of technologies, including those of post-subsistence agriculture (Hobbs and Hopkins, 1990). Unlike most other countries in this Region, Australia's primary production methodologies have not evolved from local practices developed in conjunction with existing animals and plants. This is perhaps best illustrated by the paucity of native animals and plants which Australia has developed for commercial uses.

A similar implantation of European cultural and social attitudes also inevitably occurred. Among other impacts, such attitudes led to the establishment, in the mid-nineteenth century, of government-subsidized acclimatization societies (Myers, 1986) which were dedicated to reproducing the English environment in Australia by the introduction of familiar plants and animals.

A direct consequence of this technological and social colonization was the introduction of large numbers of plants and animals to meet the needs of primary production. Today, some 63 per cent of Australia's land area is devoted to grazing exotic animals and six per cent to exotic agricultural crops (Hobbs and Hopkins, 1990).

However, there have also been harmful introductions, the consequences of which have cost the country dearly. These include the prickly pear (*Opuntia inermis*) which, at one stage, infested some 23 million ha (Norris, 1970) and the rabbit (*Oryctolagus cuniculus*) which today inhabits an area of 4.5 million sq km (Myers, 1986).

In the aquatic environment, the European carp (*Cyprinus carpio*) was first introduced into Australia in the late nineteenth century. Over the years, three strains of this species were introduced to various locations in New South Wales and Victoria. Two remained relatively sedentary. In the mid-sixties, escapees from the Boolara strain began a massive range expansion which ultimately spread along the entire length of Australia's largest river system, the Murray-Darling (Fig. 2) (Morison and Hume, 1990). Considerable resources were expended in trying to eradicate feral populations and to control the spread of this species. To date, there are no known, long-term control measures available for large or unconfined carp populations (Morison and Hume, 1990).

Not all introductions are considered deleterious to this country. Salmonids such as brown trout (*Salmo trutta*) are much sought-after recreational fishing species. Yet, their introduction and spread have been reported to have had deleterious effects on some native species (Arthington, 1989).

Thus, historically, introduced species in this country are largely judged by contrasting their environmental effects, real or potential, against their benefits, either social or economic.

2.2. Ecological Background: An Arid Environment and a Unique Fauna

Australia has the distinction of being the driest continent on earth. This aridity, plus a geologic isolation of some 50 million years (Merrick and Schmida, 1984), have produced a unique fish fauna adapted to the vagaries of an environment often characterized by unpredictable droughts and floods.

Approximately 180 freshwater species are presently recorded in Australia (Allen, 1989). This is a small number when compared with the more than 1,900 freshwater species recorded for Africa (Merrick and Schmida, 1984). Perhaps more importantly, Australia's piscifauna contains no representatives of the two major families of freshwater food fishes, the cyprinids and the cichlids.

These two factors, the dry, unpredictable climate and the absence of many globally popular fish families, have combined to make the Australian aquatic environment highly susceptible to invasion by exotic species.

European settlement produced environmental changes on an unprecedented scale. Many of the imported land-use practices were unsuited to the Australian environment, often leading to rapid environmental damage (Clark, 1990). Catchment degradation, in the form of land clearance for agriculture or timber extraction, has resulted in sedimentation, nitrification, and increasingly, salinization of waterways (Lake and Marchant, 1990). Dams and weirs affect aquatic communities by altering thermal regimes, flow patterns, and blocking migration (Lake and Marchant, 1990). Stream banks are cleared of vegetation, stream channel morphology is altered, and obstacles to

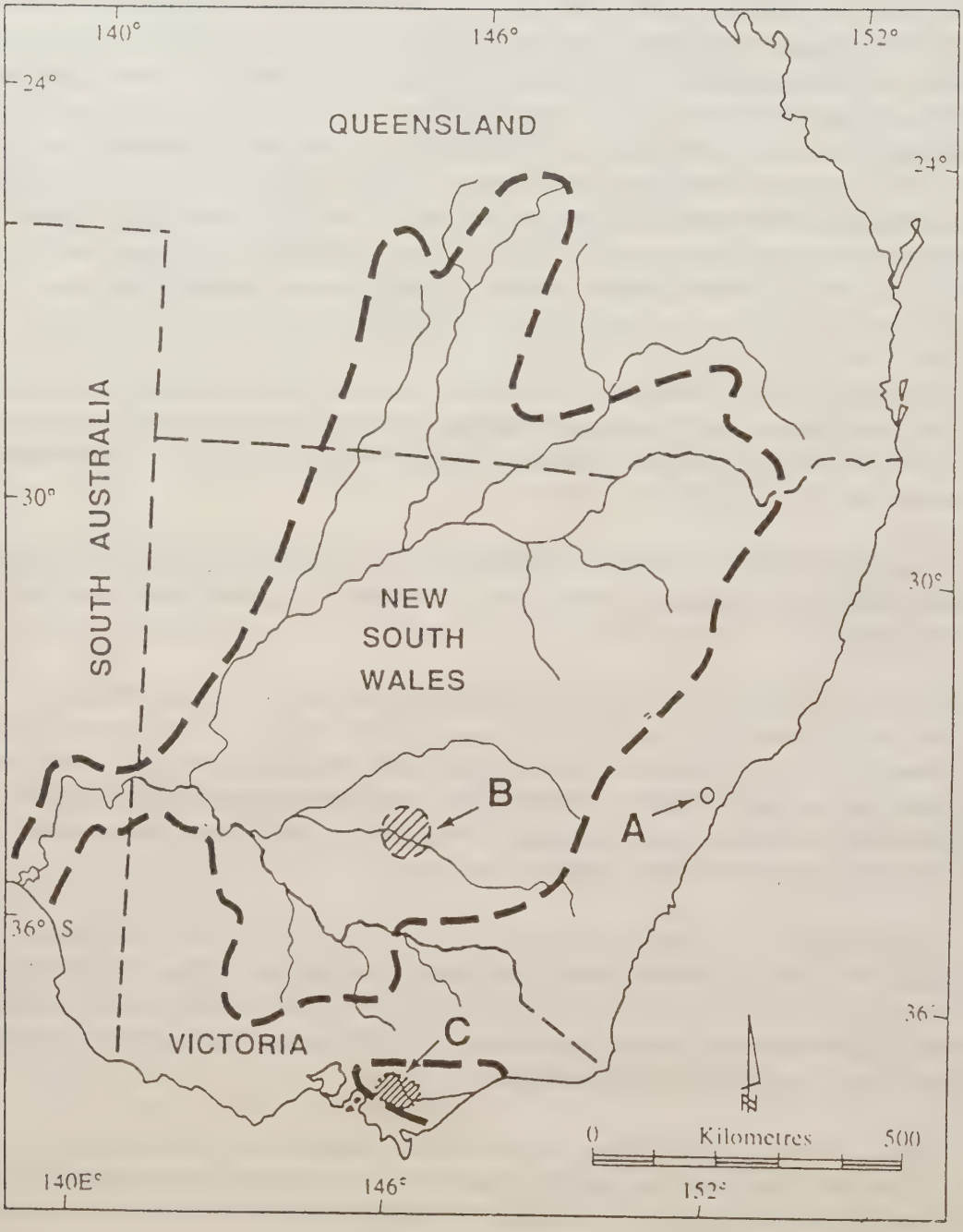

Fig. 2. Original distribution of the three strains of *Cyprinus carpio* in Southeastern Australia (A, Prospect reservoir strain; B, Murrumbidgee Irrigation Area strain; C, Boolara strain). The heavy dashed lines indicate the expanded distribution of the Boolara strain in 1977 (redrawn from Pollard *et al.*, 1980).

flow, such as tree trunks and logs, are removed. Such habitat destruction and modification is a prime contributor to declines in native fish numbers (Cadwallader, 1978; Pierce, 1989).

Population centers and irrigated primary industries require abundant, reliable water supplies. These requirements are increasingly being met by the damming of streams which results in the impoundment of large bodies of water. In the absence of naturally occurring lakes (at least on the Australian mainland), few native species are adapted to live permanently in impoundments and reproduction often fails (Cadwallader, 1978).

Industrialized and urbanized areas often introduce pollutants and nutrients into waterways which, again, reduce the quality of the habitat available for native fishes.

On the other hand, the establishment of impoundments and other new habitats creates conditions which are often ideal for exotic species (Arthington *et al.*, 1990). Pre-adapted to low water quality or modified habitats, and largely relieved of the dangers of predation, exotic fishes such as carp, roach, redfin, tench, goldfish, *Gambusia*, and tilapia have established feral populations in Australia (McKay, 1989), often with deleterious effects on native species (Arthington, 1989).

Compounding the situation is the paucity of knowledge about much of Australia's freshwater aquatic biota (Anderson, 1989; Allen, 1989). Many streams remain unsampled and many fish species remain unrecorded or undescribed (Allen, 1989). With such basic scientific investigation remaining to be done, it is a matter of little surprise that the complex ecological relationships between fish and their environment can presently only be estimated.

In summary, the destruction of habitat and the blocking of migration routes serve to disadvantage native fish populations. The establishment of artificial environments, such as impoundments, and the modification of in-stream habitats often actively assist introduced species to become established. A lack of basic scientific knowledge about many native species makes effective management difficult.

2.3. Sociological Background: Consumption of Freshwater Fish

Early European settlement tended to concentrate on the coast of Australia so much so that, even today, all of Australia's major cities are sited on the coast and most of the population lives in a narrow belt along the southeast coast. Marine and estuarine fishing became the major source of fisheries-based food supplies. In recent times, commercial freshwater fishing has contributed less than two per cent of Australia's annual fisheries production, much of which is used for bait rather than as a food source (MacKinnon, 1987).

Animal protein from other sources, such as sheep and cattle, is also readily available. Thus developed a human population not lacking in protein sources and looking towards the sea for the bulk of its fishing resources. There are two exceptions to this general scenario. The first is a demand for sport fishing opportunities in rivers and newly established impoundments, centered on introduced salmonid species and, to a growing extent, on hatchery-bred native species. The second is an unquantified demand for the various carps and tilapias by ethnic groups who are familiar with, and whose cuisine incorporates, these fishes. This demand is mostly met by substitute species at present.

In essence, Australia is, in the main, a well-fed country with abundant, affordable supplies of animal protein. This situation is in marked contrast to many Asian countries where fish contribute, on average, 33 per cent of animal protein (Chua, 1986). Fisheries in Bangladesh, for instance, provide 80 per cent of the animal protein available to the people (Aguero, 1986) and in Sri Lanka, fish provide about 70 per cent of the animal protein intake of the population (Subashinghe and Godakanda, 1986). Similarly, freshwater fish are reported to be the most important traditional protein source in West Java (Zainal *et al.*, 1990) and are an important potential source for the protein-deficient rural population of Papua New Guinea (Coates, 1987).

2.4 The Tilapia Question: Overseas Experiences

A number of Indo-Pacific countries have had problematic relationships with tilapiine species. *O. mossambicus*, for instance, enjoys a mixed reception. This species was the first of the tilapias to be introduced into Asia, being initially recorded in Java in 1939 (Riedel, 1965). In the next two decades, the prolific growth and ease of culture prompted continued dispersal of *O. mossambicus* throughout the Asian and Pacific regions (Philippart and Ruwet, 1982; Welcomme, 1988).

As time progressed, however, *O. mossambicus* was found to have some undesirable features that made it unsuitable for intensive culture. Its prolific breeding tended to lead to overpopulation of waterbodies resulting sometimes in the elimination of co-occurring species and the production of undersized or stunted individuals (Shetty *et al.*, 1989; Ang *et al.*, 1989; Juliano *et al.*, 1989; Chou and Lam, 1989). *O. mossambicus* was relegated to an unwanted and occasionally, pest, status (Welcomme, 1984).

Introduced into most of the countries of Oceania at one time or another (Welcomme, 1988), *O. mossambicus* was reported to have become established in milkfish (*Chanos chanos*) ponds in both Nauru and Kiribati (T. Petr, pers. comm.). These invasions are reported to have caused the decrease of milkfish production through competition for food (Ranoemihardjo, 1981) and eradication programs, using the piscicide rotenone, were largely unsuccessful.

An invasion of the marine habitat was reported at Fanning Atoll in the Line Island Group (Lobel, 1980). In this instance, the invasion and spread of *O. mossambicus* is anecdotally blamed for a decrease in mullet, bonefish, and milkfish supplies.

In the Indo-Pacific region, some countries, such as Sri Lanka, India, Indonesia, Papua New Guinea, and the Philippines continue to utilize feral stocks of this species for food production. The present position of *O. mossambicus* in Asian countries is summarized in Table 1 drawn from information presented at the Asian Fisheries Society Workshop on Exotic Aquatic Species held in Darwin in 1989 (De Silva, 1989a).

Table 1
Status and source of Asian populations of the African cichlid, Oreochromis mossambicus.

Country	Year/Introduced from	Status
Australia	unknown	prohibited import
China	1957, Vietnam	not suitable for culture
India	1952, Thailand and Sri Lanka	pest, commercial reservoir fishery, sometimes cultured
Indonesia	1939, unknown	food fish, trash fish, malaria control
Japan (Okinawa)	1954, Thailand	not stated
Malaysia	1944, Java	nuissance, culture discouraged, sport fish in reservoirs
Philippines	1950, Thailand	nuissance fish although also food fish
Singapore	1942, Java?	common, not utilized for food
Sri Lanka	1952, Malaysia	food fish
Taiwan	1946, Singapore	pest
Thailand	1949, Malaysia	cultured food fish

2.5. The Tilapia Question: Australian Populations

2.5.1 Distribution

A number of viable feral populations of *O. mossambicus* presently exists in Australia, and reports of new ones are relatively common. In some cases, these are localized and can be eliminated; in others, the population is too widespread for immediate control. The established populations are believed to have originated largely from the release of aquarium specimens and from ornamental ponds during flooding (Arthington *et al*, 1984). Currently, the known populations of this species are centered on three urban areas of Queensland (Brisbane, Townsville, and Cairns) and the Gascoyne-Lyons river system in Western Australia (Fig. 3) (Bluhdorn *et al.*, 1990). The Cairns area also supports feral stocks of the blue tilapia, *Tilapia mariae*.

2.5.2 Genetic relationships

The *O. mossambicus* stocks represent two distinct genetic strains. The southern strain is found in Brisbane, Townsville, and the Gascoyne-Lyons system. The northern strain exists in the Cairns area. Electrophoretic comparisons with reference tissues from Stirling University in Scotland show that the southern strain is a relatively pure strain of *O. mossambicus*. The northern strain appears to be a hybrid largely based on *O. mossambicus* but with gene introgression from *O. hornorum* and possibly, *O. niloticus* (Bluhdorn *et al.*, 1990).

Both these strains have produced stunted and non-stunted populations but no genetic differences have been detected between the two growth forms of the individual strains (Bluhdorn and Arthington, 1990a).

Fig. 3. The known sites of established *O. mossambicus* populations in Australia.

2.5.3 Populations and their habitats

Of the two major populations in the Brisbane area, the North Pine Dam population could be characterized as a normal-sized example, growing to 35 cm standard length and two-kg wet weight (Bluhdorn *et al.*, 1990). Comparisons with overseas population characteristics indicate little difference between this and other full-sized populations of *O. mossambicus* (Bluhdorn and Arthington, 1990b). The second, from Tingalpa Reservoir, grows neither so large nor so plentiful and shows early signs of stunting (Bluhdorn and Arthington, 1990a). Both of these populations inhabit water supply reservoirs with good water quality and scarce (Tingalpa) to abundant (North Pine) macrophyte resources. There are no native fish large enough to prey on adult tilapia but some predation of fry and small juveniles by the native spangled perch (*Leiopotherapon unicolor*) and eels (*Anguilla* spp.) would occur. There may also be some interaction over breeding territories between *O. mossambicus* and a nest-building native species, the eel-tailed catfish, *Tandanus tandanus* (Bluhdorn *et al.*, 1990). Occasional flooding allows the escape of many individuals and there are reports of viable populations becoming established in waters downstream from both impoundments.

In Townsville, the *O. mossambicus* population inhabits the extensive drain system of the city (Arthington *et al.*, 1984) where they grow to approximately 30 cm SL and show no signs of stunting. The drains are tidally flushed by the operation of floodgates, which allows the occasional intrusion of estuarine species such as milkfish (*Chanos chanos*) and mud crabs (*Scylla serrata*). Predacious fishes are not usually observed in the drains. Flooding of the drains has allowed a slow range expansion by *O. mossambicus* up the Ross River but a series of weirs prevents rapid colonization. A recent expansion of the population has occurred in a newly constructed artificial lake connected to the drainage system and the potential for further spread in this flat floodplain site by either human or flood-induced translocation, is considerable.

In the Cairns area, *O. mossambicus* occupies *Melaleuca* swamps and tidal estuaries of short coastal streams. In most locations, these fish grow to full size and share their habitat with another cichlid (*Tilapia mariae*) and a range of piscivores including barramundi (*Lates calcarifer*) and mangrove jack (*Lutjanus* spp.). The salinity of these sites varies from that of seawater to freshwater, depending on rainfall. One isolated, turbid pool (Guthries pond) enriched with septage and bird wastes, supported a large population of stunted individuals. Northward expansion of these Cairns tilapia has been facilitated by direct, illegal, human translocation.

To a greater or lesser extent, all of the above populations inhabit environments severely altered from their natural condition and it can be argued that habitat modification has played as great a part in the invasive process as the tilapia's own invasive abilities. However, one very successful population occupies a virtually pristine environment in which habitat modification appears to have played very little part.

The Gascoyne-Lyons river system drains an arid area of the southern Pilbara region of Western Australia. Sparse and infrequent rainfall means that this river system has only intermittent and often localized flow events. However, in less than 10 years, *O. mossambicus* has colonized almost the entire length of the system. The harsh conditions have produced a population which is very stunted, and in which sexual maturity is reached at approximately eight cm standard length and at less than eight months of age. This allows the population to expand and reproduce quickly during the brief flow events, facilitating its widespread dispersal throughout the catchment. The same stunting strategy allows survival at high population densities in refugia during periods of no flow. One possibly negative result of this strategy is that the co-occurring spangled perch (*Leiopotherapon unicolor*) is now, by comparison, much larger than the tilapia and preys upon mature but stunted fish.

2.5.4 Disperal

On a broader scale, two dispersal agents appear to be at work in the spread of this fish.

Natural dispersal occurs primarily via flooding which causes the infested impoundments to overflow and flush adult tilapia downstream. Their later survival also depends, in part, on the habitat disruption caused by the flood. In Townsville, juvenile migration appears to have been responsible for the invasion of a newly constructed artificial lake (mesh screens were installed to block adult infiltration). This has facilitated expansion by *O. mossambicus* in this area.

By far, the most common method of dispersal is that of human translocation which is responsible for most of the infestations that presently exist. Strictly speaking, all transfers of fish from one waterbody to another require official approval but, in reality, there are no practical barriers to translocation anywhere in the country at present. Thus the best, and only practical, way to control the spread of an exotic fish in this country is at the point of entry. Once the fish is introduced, effective barriers to human translocation are non-existent.

2.5.5 Problems

The feral populations of *O. mossambicus* in Australia exhibit the features and problems of populations elsewhere in the world. Some grow to full size and are relatively sedentary with low population densities. Others are stunted and overcrowded. Direct effects on native species have yet to be proven but could include competition for food and territorial resources. Two different strains already occur and the potential for interspecific hybridization exists (Arthington, 1989).

The major problem posed at present by *O. mossambicus* is that of range expansion. In the urban environments in which the Queensland populations exist, human translocation, either deliberately or through the effects of development, is the

primary dispersive element aided by occasional flooding. There are no effective barriers to deliberate translocation in spite of the severe penalties which can be incurred under existing legislation.

In the more pristine environment of the Gascoyne-Lyons river system, it appears that the fish's own invasive potential is being employed successfully to ensure continual recolonization of the system after droughts and periods of no flow. This example exposes perhaps the greatest threat to Australia's waterways since it extends the potential range of *O. mossambicus* from the tropical north into the vast, interior arid zone and therefore, almost every major river system in the country.

2.6 Responsible Authorities: Federal and State

On an Australia-wide basis, responsibility for imported fish species rests with the Commonwealth Department of Primary Industries and Energy and the Australian National Parks and Wildlife Service. Regulations under the Quarantine Act and the Wildlife Protection Act (Regulation of Exports and Imports) are enforced by the Australian Quarantine and Inspection Service. The Advisory Committee on Live Fish (ACOLF) makes recommendations to the Standing Committee on Fisheries on the species permitted importation into Australia, and these recommendations are based on a number of criteria (Michaelis, 1989).

A fish species would be excluded from importation if, among others, it exhibits:

(i) any history of forming feral populations or caused significant problems elsewhere;

(ii) the capacity for survival and dispersal within Australia;

(iii) any likelihood of having a significant detrimental impact on other fish species or wildlife, or on the aquatic environment;

(iv) the ability to carry diseases not yet found in Australia; or

(v) the potential for growth to a large size.

Under all of these criteria, tilapiine species would fail to be included on the list of permissible imports.

Fisheries management is the responsibility of individual State and Territory Governments within their own boundaries. Each of these governments has a representative on ACOLF as well as their own policies for the internal management of exotic species. Most of these governments have a policy of prohibiting, or otherwise discouraging, the importation, translocation, or possession of tilapias.

3. UTILIZATION OF THE AUSTRALIAN RESOURCE

Although the utilization of tilapias within Australia is shown to be both ecologically unwise, economically unsound, and legally untenable, some opportunities exist for the international exploitation of the unique properties of Australia's feral tilapia populations.

Oreochromis mossambicus has played and, indeed, still plays an important role in providing a source of scarce protein for the poor in some Asian countries. As suggested by Costa-Pierce *et al.* (1988), "For the very poor in both Indonesia and the Philippines, *Oreochromis mossambicus* has been and will always be a gift of immeasurable importance".

Moreover, a number of other countries which are involved in extensive subsistence culture of *O. mossambicus*, are beginning to experience declining catches because of the effects of overfishing, inbreeding, and hybridization of stocks (De Silva and Amarasinghe, 1989; De Silva 1985). Australian strains, especially the southern one, are relatively pure and have the good growth characteristics of the species under optimal conditions. These populations could be valuable to overseas countries in two ways:

(i) as broodstock to re-introduce pure strains of the preferred culture species; and

(ii) as field laboratory stock to discover the conditions which induce stunting and the physiological mechanisms which cause it.

The second point above is an area of research that has been largely overlooked. The more developed countries in the Region have focused on solutions appropriate for intensive culture, such as fast-growing hybrids, monosex production, sterile populations, etc. Such are not available or necessarily suitable for Papua New Guinea, Sri Lanka, Indonesia, or India. *O. mossambicus* often remains the mainstay of subsistence fisheries and, therefore, a vital source of animal protein, income, and employment for the poor (De Silva, 1989a).

4. DISCUSSION

From a historical perspective, the imposition of a completely new civilization, including attitudes, technologies, animals and plants has caused unprecedented changes to the environment of Australia. Much of this new order has been beneficial, some of it disastrous, and some producing equivocal effects, such as salmonid stocking which provides appreciable economic and social benefits but at substantial economic and environmental cost.

Ecologically speaking, Australia has suffered from many of the mistakes made about introduced species. The aquatic environment has had, and still has, significant problems to overcome in terms of habitat degradation, impoundments, salinization, and

pollution. These factors all impact on native fish populations and many of them produce ideal environments for invasive species. Compounding this situation, a lack of basic scientific knowledge about many native species makes effective management difficult.

Sociologically, Australia could be classified as a well-fed country with abundant, affordable supplies of animal protein. Fish protein, as a basic food resource, is supplied cheaply from the sea.

None of these background perspectives is particularly receptive to the idea of introducing yet another exotic species. There appear to be too few benefits available from tilapia culture to make the risks worthwhile.

From a management point of view, the existing tilapia populations present an almost insurmountable problem in trying to contain their range expansion. Lack of effective control measures on translocations and tilapia's own invasive and survival abilities mean that under current funding and staffing levels, the feral populations will continue to expand.

This realization, combined with the background material previously mentioned and the lack of potential economic benefits of sufficient scale, has led the various authorities responsible for the aquatic environment to prohibit the culture of tilapia in most states of this country. From a pragmatic perspective, the lack of internal controls on translocations means that the most appropriate initial management strategy is to prohibit the importation of tilapias into the country. They are not currently needed as a food resource and other, more appropriate species are available for aquaculture.

However, despite the country's negative attitude to tilapias, Australia should not be overlooked as a potential source of pure *O. mossambicus* strains and of research into areas applicable to extensive culture or subsistence fisheries.

5. ACKNOWLEDGMENTS

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TILAPIA IN BANGLADESH

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1. INTRODUCTION

Oreochromis mossambicus was introduced into Bangladesh from Thailand in 1954. The species was quickly propagated in ponds and fry were distributed for culture all over the country although the species thrived better in ponds of central and southern Bangladesh. The other species, *O. niloticus*, was transplanted in Bangladesh from Thailand in 1974 and was stocked in a sewage-fed lake in Dhaka and in ponds of the Fishery Research Institute at Chandpur. Like *O. mossambicus*, this species did well and multiplied rapidly and adults/juveniles of the species were distributed in Government and private fish farms throughout the country. The above introductions were not put under quarantine and no information about the quality of the strains was available during transplantation.

2. PRODUCTION

Reliable statistics on the total production of tilapia from different waterbodies in the country are not available. However, the Department of Fisheries (DOF) estimates the total production of tilapia from approximately 147,000 ha of ponds to be about 1,643 mt, or approximately one per cent of the total fish production from ponds in 1988-1989.

Production of tilapia from about 100,000 ha of shrimp farms in the coastal areas is estimated to be 1,069 mt, representing approximately 20-35 per cent of the total white fish harvested from shrimp farms. (Tilapia are not stocked in shrimp farms but enter the system during water exchange from the saline water creeks, where they appear to have established themselves.) In the sewage-fed ponds and lakes of Dhaka City, another 300 mt of tilapia are harvested.

On the basis of the above, the national production of tilapia, including the catch from Kaptai reservoir, comes to about 3,015 mt which is about 0.36 per cent of the total production of fish in the country from all sources. This appears to be an underestimate since the sample survey used by the DOF for catch assessment is not representative.

2.1 In Ponds

Data on growth and yields from ponds during the early days of tilapia introduction are not available. However, in the case of *O. mossambicus* which thrived well in ponds of the Chandpur-Comilla area, overcrowding and stunting of stocks were reported. Sudden disappearance of stocks from ponds was also reported by public and private pond culturists during the early 1960s. The matter was investigated and confirmed but no reason for such behavior could be identified. Earlier (1965) experiments on monosex culture of *O. mossambicus* in ponds of the Fisheries Research Institute indicated faster growth of males as compared to the females or mixed sexes. Separation of tilapia juveniles on the basis of sex did not work well and the stock usually got mixed up and started to breed in ponds. The mixed culture of *O. mossambicus* and carp resulted in poor growth and lower production per unit area of carp as a result of competition with tilapia in the same environment.

O. niloticus has shown better success than *O. mossambicus* as manifested by the appearance of individuals weighing 500-700 g in the markets of Dhaka City throughout the year. On-station (FARS, Mymensingh) culture undertaken to test the performance of *O. niloticus* has produced a crop of 3.5 mt/ha in six months with supplemental feeding consisting of mustard oil cake and rice bran. Fertilization of ponds in addition to supplemental feeding raised production to 4.2 mt/ha in six months although the market-sized individuals comprised only 60 per cent of the harvest. Extensive culture trials with weekly application of fertilizers such as cow dung at 375 kg/ha, TSP at 16 kg/ha, and urea at 8 kg/ha, produced a crop of only 1.5 mt/ha after a rearing period of six months. In the case of red tilapia, a comparably higher production level of 3.2 mt/ha was obtained in six months with supplemental feeding and the market-sized fish constituted 97 per cent of the harvest.

Under the DANIDA-assisted Aquaculture Extension Project in Mymensingh District, small, seasonal, derelict ditches (3-5 decimals) which retain water for three to five months a year, were utilized for raising *O. niloticus* with good returns for the village pond owners. Yields varied from 1,000-1,800 kg/ha for a rearing period of 3-5 months. The cost of operation ranged from Taka 12,500-32,500/ha and net profit varied between Taka 25,000-29,600/ha. Small seasonal ditches including roadside burrowpits, which normally do not produce any crop and where culture of other species is not possible, offer an excellent opportunity for increased production of fish and additional income for the poor marginal farmers.

It has been observed, however, that it is extremely difficult to remove or eradicate tilapia in deeper ponds which retain water throughout the year where tilapia is well-established. In some ponds of the Fishery Research Institute at Chandpur, efforts to eradicate tilapia (like dewatering and drying of ponds, application of high doses of lime, and removal of a layer of bottom soil) failed to get rid of the fish when it became a menace in 1978. New stocks appeared when the ponds were recharged with rain or underground water.

To keep the tilapia population under control in a pond of the Fishery Research Institute at Chandpur, snakehead juveniles were introduced. It was, however, not possible to use tilapia as forage for the snakehead. Soon, the tilapia population outnumbered the snakehead and only a few individuals fed on the tilapia fry and fingerlings; the others became sickly and died.

2.2 In Sewage-fed Ponds and Lakes

Eleven ponds, which used to receive garbage and town sewage and with a water area of 40 ha, around Adamjee Jute Mills near Dhaka City had been producing a crop of 5.6 mt/ha/yr, of which *O. niloticus* contributes about five mt/ha/yr. Harvesting is done five to six times a year and individuals of 250 g and above are usually harvested.

In the 20-ha sewage-fed Dhanmondi Lake in Dhaka City, an average crop of four mt/ha/yr has been produced in the last 10 years, of which *O. niloticus* contributed three mt/ha/yr with no fertilization and feeding. Average size at harvest is 250 g.

2.3 In Cages in Kaptai Reservoir

Culture of tilapia in cages in the 68,000-ha Kaptai reservoir was undertaken by a number of sub-borrowers under the ADB-assisted Aquaculture Development Project. As feed availability was a constraint and the venture proved to be a losing concern, it was subsequently abandoned although the tilapia fry that escaped from the cages grew and reproduced in the lake. Prior to the introduction of cage culture in Kaptai lake in 1986-1987, tilapia was not represented in the catch of the lake. Since then, the contribution of tilapia to the total fish landing in Kaptai reservoir has grown, although still in insignificant percentages, as shown below:

Year	Total fish catch (in mt)	Quantity of tilapia in the catch (kg)	Percentage of tilapia in the catch
1986–87	3,980.55	547	0.013
1987–88	4,068.40	164	0.004
1988–89	3,439.23	811	0.023
1989–90	3,713.01	2,981	0.080

The maximum size of tilapia recorded in the catch of Kaptai reservoir was found to be 3-3.75 kg each whereas the average size at landing was 500 g each.

2.4 In Inland Open Waters

There is no record of tilapia harvest from the open inland rivers. Despite its propagation and culture in ponds which occasionally get inundated during annual flooding, tilapia could not establish itself in the inland openwater capture fishery system.

However, tilapia appears to have established populations in brackishwater creeks and canals in the coastal districts since fry enter the brackishwater shrimp farms when pond water is changed during high tide.

3. CONCLUSION

Many pond owners in the country are poor and are not capable of investing enough money for the purchase of inputs for their ponds. Their ponds therefore remain derelict. Since culture of *O. niloticus* is a low-cost operation with good financial returns, poor marginal farmers have been encouraged to culture the species in small seasonal ponds, ditches, and micro-impoundments which produce almost no crop. However, as the species is exotic and is not as acceptable to the population as the local perch, the need of the hour is to extend the culture technology and to motivate the local farmers to use it for growing to marketable size.

PERFORMANCE OF TILAPIA IN INDIAN WATERS AND ITS POSSIBLE IMPACT ON THE NATIVE ICHTHYOFAUNA

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1. INTRODUCTION

There is no other species of fish that has generated so much controversy in India as tilapia. In the early phases of inland fisheries development in India, it was considered prudent to introduce an alien species which adapted well, bred profusely, subsisted on a variety of food under diverse ecological situations, and contributed substantially to the country's fish production. Thus came the tilapia, *Oreochromis mossambicus,* to India. However, the fish failed to live up to its promise. Its long-term performance in some of the waters and its biological plasticity have posed a series of questions on its desirability in waters which harbor a highly rich and diverse native ichthyofauna. While tilapia's capability of making a sizable contribution to the yield remains unquestionable, the argument for and against the species centers more around its impact on the co-existing endemic fauna, an apprehension prevailing the world over. In the absence of an in-depth biological probe on the species in the Indian context, the doubts being raised about the species still remain unanswered.

2. INTRODUCTION OF THE SPECIES INTO THE COUNTRY

In India, the first consignment of *O. mossambicus* was brought in by the Central Marine Fisheries Research Institute (CMFRI), Mandapam (Tamil Nadu), on 7 August 1952 from Bangkok (Panicker and Tampi, 1954). The second consignment was also brought in by the Madras Fisheries Department from Ceylon in the same year (Devadas and Chacko, 1953). A small stock of tilapia from Mandapam was taken to the Pond Culture Division of Central Inland Capture Fisheries Research Institute (CICFRI) at Cuttack, Orissa in December 1953 for detailed experimentation on the biology and culture and to evaluate the probable impacts of its culture and propagation on Indian carps.

The Government of India was cautious in introducing the fish and therefore restricted it to areas south of Vaigai river (Madurai district), leaving the North Indian rivers the natural abode of Indian major carps. The State Government of Madras, through its Fisheries Department, spread the species throughout the State, even north of Vaigai river, with great hopes (Sreenivasan, 1967). The State Government was also responsible for the shifting of the species from the experimental stage to the commercial

fishery. Almost at the same time, the species was stocked in the reservoirs of Kerala, as revealed from the stocking data for the year 1956 of the Meenkara reservoir in Palghat district. By the late 50s and early 60s, almost all small reservoirs of Tamil Nadu and the reservoirs of Palghat and Trichur districts of Kerala were stocked with tilapia and the species began to dominate the catches from these waterbodies. Swiftly, the species found its way to the small and large tanks and ponds of both states, and also to the neighboring states of Karnataka and Andhra Pradesh. Soon after, *O. mossambicus* became an integral part of the fishery in many ponds and wetlands (*bheries*) of Bengal. The fish now forms a part of the Kalahandi district in Orissa. From the ponds belonging to the tribals of Kalahandi district, the stock found its way to the Sondur reservoir of the Raipur district through the flood waters of Sondur river, and began contributing significantly to its fishery from 1989 onwards. The species was first introduced into the Kolleru lake area in Andhra Pradesh in 1988 in the aquaculture tanks of Sriparru village, having been accidentally brought from Calcutta along with major carp seed. By 1990, it gained a wide distribution among several tanks on the western and northern parts of the lake. In commercial capture fisheries of the lake, specimens of tilapia were first detected in 1989.

The first entrance of *O. niloticus* to the country is not documented. It is suspected that the species was brought by the West Bengal Farmers in the early 80s. However, the species is now widely available to the farmers of the Region and is also reared extensively in many of the sewage-fed *bheries* of the State.

3. PERFORMANCE OF *O. MOSSAMBICUS* IN INDIAN WATERS

The performance of *O. mossambicus* in different waterbodies, including the culture-based capture systems, has been assessed by several authors. The results of early experiments at CICFRI have largely been confined to the reports of the Institute. Menon and Chacko (1957), Menon and Krishnamoorthy (1956), and Menon et. al. (1959) have tried to ascertain the performance of the fish in respect to its feeding habits, growth, and possibility of raising it as forage for the murrels under culture. Sreenivasan (1967) has summed up the utility of tilapia in Indian waters based on his elaborate analysis of its performance in Tamil Nadu waters. This seems to be the only serious and critical evaluation of species in India until the 80s, taking into consideration both its bio-ecology and production trends. Most other literature on the species is restricted to its yield prospects, studies on sex reversal, and the physiological responses to environmental stresses. The second comprehensive review on tilapia in Indian waters was by Jhingran (1983) who analyzed in detail the pros and cons of tilapia's performance, expounding on its role in the capture fishery systems of India.

The Committee for Introduction of Exotic Aquatic Species in India, which was set up by the Government of India, has also gone into the details of the species and the possible impact of its large-scale adoption in Indian waters for enhancing fish production. Several of the commercial houses are coming up in a big way by employing biotechnological approaches to tilapia farming, the most prominent among them being the venture of M/s Vorion Chemicals and Distilleries Ltd. (VCDL), Madras, which is

culturing the hybrid variety "golden tilapia" (Rangaswami, 1988). Vorion VCDL is reported to have achieved a production rate of 65 mt/ha/yr in its farm. The following paragraphs give an up-to-date information on the performance of *O. mossambicus* in selected Indian waters.

3.1 In Fishponds

In India, tilapia culture trials were conducted in ponds as early as the 50s. The experiments at the CICFRI Cuttack Center revealed that the species adversely affected the survival and growth of carp seed in nurseries. Further, tilapia up to 50 mm length have been observed to feed directly on carp fry. Extreme competition for food was demonstrated by the very low survival and poor growth of major carp fry in nurseries. The weight of carps stocked in culture ponds along with tilapia was much lower than the weight of fish grown in exclusive carp ponds (Anon., 1959). The monoculture of male tilapia yielded comparatively better results. But in some cases, the few female tilapia, finding entry to ponds, could jeopardize the stock density and defeat the purpose of its monoculture (Anon., 1961).

Panicker and Tampi (1954) found tilapia in aquaria growing to 15, 28, 35, 39, and 55 mm at the end of the first, second, third, fourth, and fifth months, respectively. A growth of 160 mm in eight months in an irrigation well has been reported in Madras. Devadas and Chacko (1953) recorded a growth of 60 mm in eight months.

According to the CICFRI Cuttack Research Centre, a daily growth of 1.5-2 mm was observed in *O. mossambicus* in culture ponds. In another experiment, when stocked at 2,500 individuals/ha, the fish grew to 187.5 mm and 103.75 g from an initial size of 128.5 mm and an initial weight of 31 g in two months. Under monosex culture at a stocking density of 3,000 individuals/ha, specimens with an average length/weight of 142 mm/53.12 g grew to 300 mm/454 g in 12 months and to 500 g in 14 months. In the third experiment, when stocked along with Indian major carps and Chinese carps at 3,750 individuals/ha (tilapia, 625/ha), tilapia males weighing 104 g grew to 340 g in 6-1/2 months.

Initial results of tilapia farming in sewage-fed farms were extremely encouraging with yields of around 8,000 kg/ha. Uncontrolled breeding and subsequent stunting brought down the yield to around 3,000-4,000 kg/yr, however.

3.2 In Tanks

O. mossambicus is reported to occur in ponds and tanks of peninsular India and a few tanks in the Raipur City of Madhya Pradesh (Tables 1 and 2).

Table 1

Contribution to the total catch by species or groups in major tanks in Tamil Nadu, 1989–1990

Species/groups	Large tanks		Seasonal tank and other ponds	
	Yield (kg)	% of total catch	Yield (kg)	% of total catch
L. rohita	2736	18.9	3390	12.5
C. catla	774	4.2	2540	9.4
C. mrigala	–	–	845	3.1
Major carps, total	3510	24.3	6775	21.9
Common carp	10566	73.0	17220	63.7
O. mossambicus	396	2.7	2780	10.3
Catfishes and murrels	–	–	240	0.9

Source: Department of Fisheries, Tamil Nadu.

Table 2

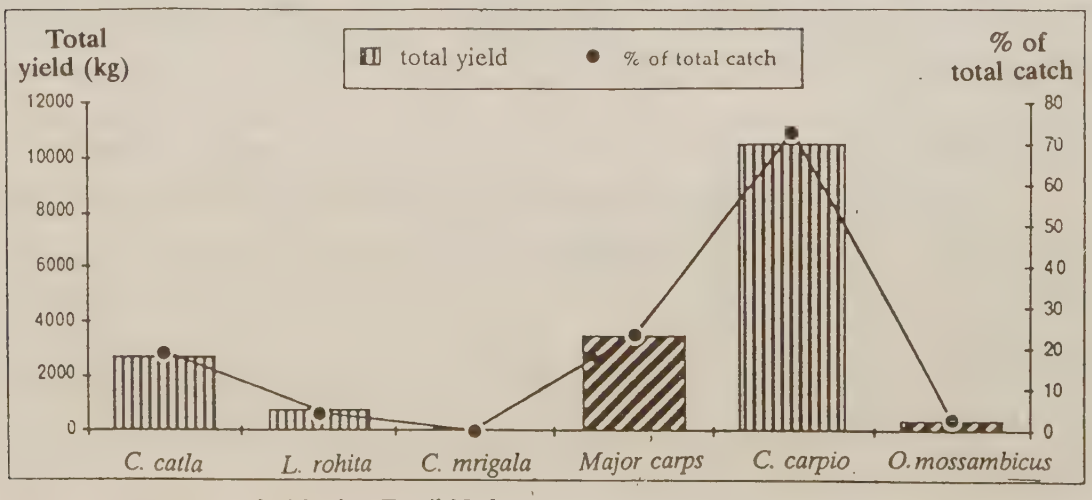
Yield of *O. mossambicus* from tanks of Raipur district, Madhya Pradesh.

Tank	Area/depth (ha/m)	Contribution by tilapia		Total yield from tank	
		(kg/ha)	(%)	(kg/ha)	(%)
Budha Talao	22/3	590	55	1074	36.5
Maharaj bundh	5/3	Fairly good		N.A.	
Naya Talao	5/3	1980	66	3000	15
Teligandha	N.A.	Fairly good		N.A.	

Data source: Personal communication with farmers.

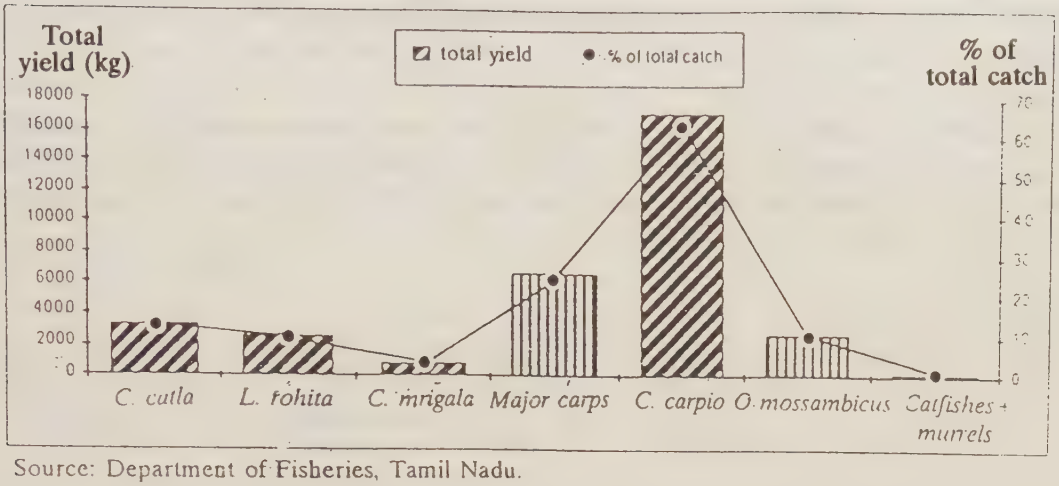
General information on the relative contribution of major carps, *C. carpio*, and *O. mossambicus* in Tamil Nadu tanks are shown in Figures 1 and 2. *C. carpio*, being heavily stocked in tanks, have been able to keep down the population of *O. mossambicus* to 2.7 per cent in large tanks and 10.3 per cent in seasonal tanks and ponds, on average.

Fig. 1. Contribution of various fishes to the yield from major tanks of Tamil Nadu, 1989-90.



Source: Department of Fisheries, Tamil Nadu.

Fig. 2. Contribution of various fishes to the yield from small tanks and ponds of Tamil Nadu, 1989-90.



Source: Department of Fisheries, Tamil Nadu.

3.3 Tilapia in wetlands (*bheries*)

O. mossambicus and, more recently, *O. niloticus* form the basis of an important fishery in the wetlands (*bheries*) around Calcutta, particularly those fertilized with raw or partially-treated sewage.

Over the period 1971-1982, the contribution of tilapia to total fish production of the *bheries* has declined from 100 per cent in 1971 to 10 per cent in 1982. In comparison, carps contributed increasingly higher percentage to total production - from 20 per cent in 1970 to 90 per cent in 1982 (Table 3).

Table 3
Trend in yield composition from wetlands *(bheries)* in West Bengal from 1959 - 1982.

Year	Total production from *bheries* (mt)	Catch composition (%)	
		Carps	*O. mossambicus*
1959	8940	93	-
1969	9670	95	-
1971	1200	-	100
1973	3500	20	80
1975	5500	25	70
1977	7400	20	80
1979	4000	50	50
1980	4500	85	15
1981	7500	90	10
1982	8500	90	10

O. mossambicus was introduced into the *bheries* in 1961 and due to its suitability for repeated stocking and harvesting, increased in popularity among the fish farmers. By 1968, the average yield of tilapia from the *bheries* was reported to be around 500 kg/ha/yr, with the individual fish growing to 100-150 g in three to four months. With the increased siltation of the *bheries* and the overcrowding of the fish population,

however, the yields decreased to 150-200 kg/ha/yr and the individual sizes dropped to 25-50 g due to stunting. These developments have served to discourage their use and fishfarmers now prefer the major carps and *O. niloticus* to *O. mossambicus*. In highly saline *bheries* where tilapia also used to be grown, farmers have shifted to the jumbo tiger shrimp, *Penaeus monodon*, which fetch better prices in the market.

O. niloticus is reported to grow to 700 g in four months or one kg or more in one year (Table 4). Provisional 1990-1991 figures obtained from farmers in two *bheries* indicate that *O. niloticus* now dominates the yield at 50-60 per cent as compared to the 20 per cent contributed by *O. mossambicus* and 20-30 per cent by the carps.

Table 4
Growth of fishes in sewage-fed *bheries*

Species	Rearing period (months)	Average weight attained (g)
O. mossambicus	8	140*
O. niloticus	8	250
Indian major carps	8	560

*Ten years before, *O. mossambicus* was reported to grow to 100-150g in four months.

3.4 In Reservoirs

O. mossambicus was stocked in many small reservoirs in peninsular India with the expectation that doing so will bring about the rapid increase in fish yield that was not achieved with the Indian major carps. (The fact was that, the reservoirs were not managed in the true sense and the Indian major carps stocked in the reservoirs took time to establish themselves.) Limited information is available, however, on stocking figure, yield, size structure of commercial catches, and trends in the fishery of tilapia and other species in several of these reservoirs. The following discussion is therefore based on inquiries rather than on conclusive documentary evidence. Nevertheless, the information presented may be adequate for some general conclusions.

3.4.1 Vaigai Reservoir

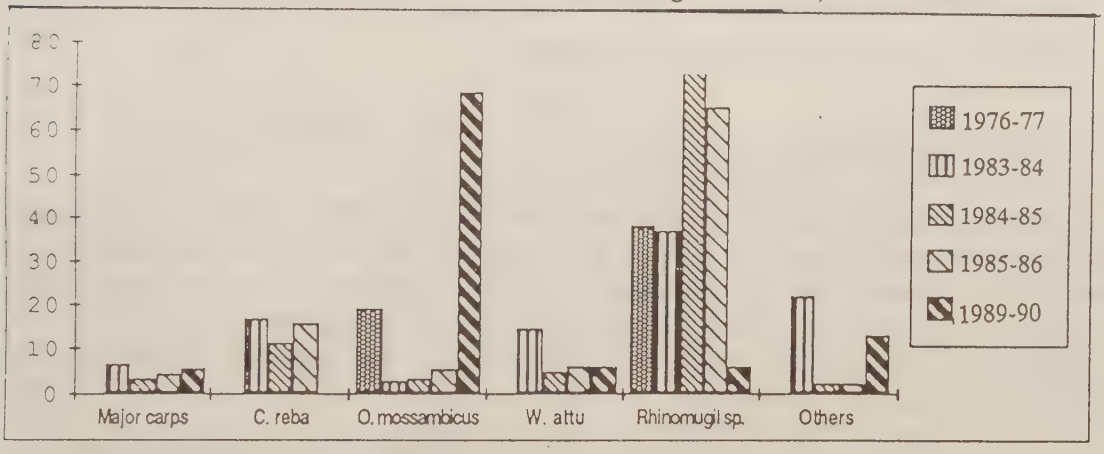
In this reservoir, with an area of 1,280 ha, *O. mossambicus* became the most important species within a few years after its introduction, contributing about 40 per cent by number and 20-25 per cent by weight from 1961-1963 (Sreenivasan, 1967). By 1976-1977, the landings from the reservoir were composed almost entirely of tilapia, contributing up to 94.2 per cent of the yield, with major carp reduced to about four per cent. In the subsequent years, however, there was a drastic change in species spectrum with tilapia declining to 0.43 per cent by 1978-1980, 0.14 per cent in 1980-1981, and no contribution thereafter. The exact cause could not be ascertained.

3.4.2 Krishnagiri Reservoir

In this 1,263-ha reservoir, tilapia has been making increasingly greater contributions to the catch. In 1976-1977, *O. mossambicus* was reported to have contributed 19 per cent to the fishery dominated by *Rhinomugil sp.* which comprised 38 per cent of the catch. This decreased to 4.3 per cent during the period 1983-1986 when mullets gave a 59 per cent contribution to the total yield of 37.6 kg/ha/yr. In 1989-1990, when fish yield in the reservoir rose to 50.5 kg/ha/yr, tilapia comprised 68.9 per cent of the catch, the highest so far, while mullets were a mere six per cent.

Through all these years, the yield of major carps has remained more or less steady at 3.7-6.6 per cent, even at the high stocking rate of 683 individuals/ha used during the period 1985-1989. The population of *Cirrhinus reba* was comparatively high at 11.5-16.8 per cent at the time tilapia production was low, but it failed to contribute to the fishery in 1989-1990 when tilapia was at its peak (Fig. 3).

Fig. 3. Fish yield (% contribution) from Krishnagiri reservoir, Tamil Nadu.

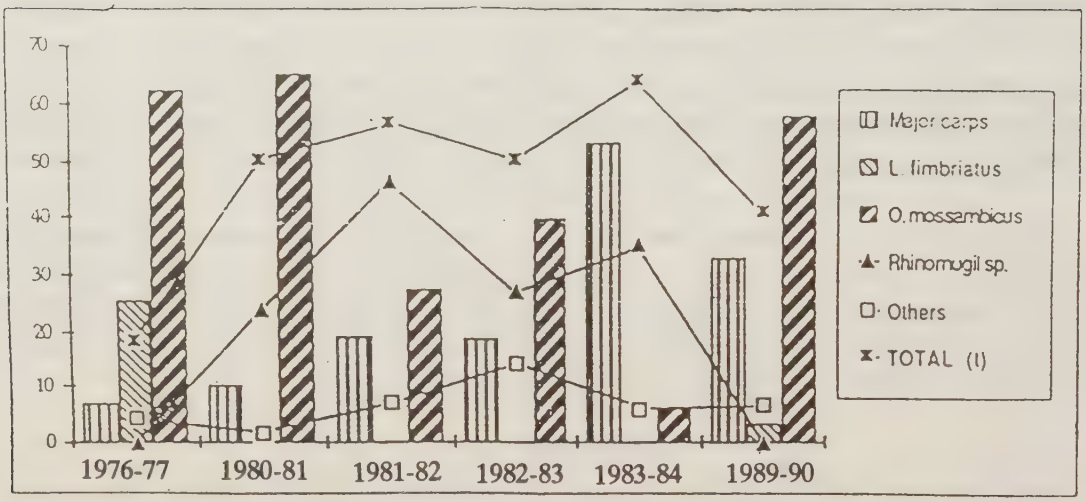


Data Source: Tamil Nadu Fisheries Department.

3.4.3 Uppar Reservoir

In this relatively small reservoir of 440 ha, the contrasting trend between the fishery of *O. mossambicus* and that of the major carps, is quite pronounced (Fig. 4). From 1976-1977, when the fish yield from the reservoir was 42 kg/ha/yr, the major carps comprised only 7.1 per cent while tilapia contributed 62.5 per cent. During the 1980-1983 period, the major carps improved their performance to 16.5 per cent and *Mugil sp.* gave 32.3 per cent to the catch, resulting in a better overall fish yield from the reservoir of 119 kg/ha/yr. At that time, tilapia contributed only 44 per cent to total catch. In 1989, the major carps comprised 33 per cent in contrast to tilapia's 58 per cent. *Mugil* has become insignificant after having been displaced by both tilapia and the carps.

Fig. 4. Fish yield (% contribution) from Uppar reservoir, Tamil Nadu.

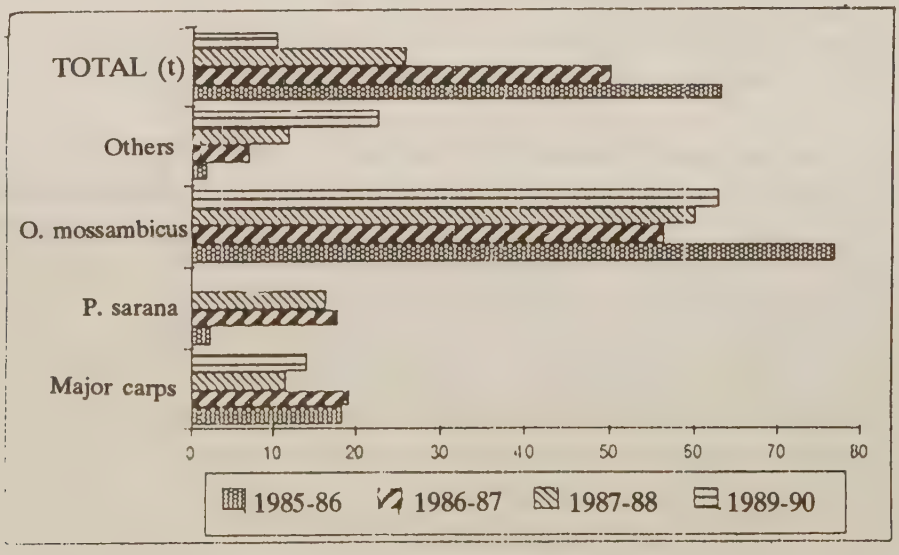


Data Source: Tamil Nadu Fisheries Department.

3.4.4 Pambar Reservoir

This is a small reservoir with an area of only 100 ha. Here, the respective contributions of major carps (11.6-19.4 per cent) and tilapia (56.6-77.2) fluctuated to a relatively lesser extent than the total yield (106-633 kg/ha/yr). The total fish yield from the reservoir was highest when tilapia production was highest (Fig. 5). The high stocking rate of 1,995 individuals/ha for major carps during 1985-1986 does not seem to have been reflected in the yield.

Fig. 5. Fish yield (% contribution) from Pambar reservoir, Tamil Nadu



Data Source: Tamil Nadu Fisheries Department

3.4.5 Chulliar Reservoir

In this 165-ha reservoir, the contribution of tilapia does not seem to bear any direct relationship with any other group of fish, with the possible exception of *Glossogobius sp.*

The major carps made insignificant contributions to the total yield until 1985 despite a stocking rate of 100 individuals/ha/yr from 1968-1978. Common carp performed poorly from 1969-1973, with a contribution of 1.2 per cent despite heavy stocking of 1,030 individuals/ha/yr during the same period. Its performance subsequently improved, though, reaching 18.6 per cent in 1973-1977 at a stocking density of 672 individuals/ha/yr. The decline in tilapia contribution from 60.1 per cent in 1969-1973 to 39.8 per cent in 1973-1977 cannot be correlated with common carp production because tilapia continued to go down even after common carp became negligible in the catch. In the same manner, tilapia's performance could not be related with that of the major carps: tilapia reached 60.1 per cent of the catch when the major carp contribution was both paltry (0.3 per cent in 1969-1973) and significant (11.46 per cent in 1988-1990) (Table 5).

Table 5
Trend and composition of fish yield, Chulliar reservoir, Kerala.

Species	Percentage contribution to the total catches					
	1969-73	1973-77	1977-81	1983-85	1985-87	1988-90
Major carps	0.3	-	0.5	0.2	5.5	11.46
	(0.06)				(0.06)	(18.7)
Puntius sp.	12.5	6.5	42.61	-	1.0	-
Glossogobius sp.	-	17.1	42.61	-	-	-
O. mossambicus	60.1	39.8	49.8	28.2	4.74	60.1
	(17.6)	(1.9)	(6.9)	(9.1)	(5.2)	(27.9)
C. carpio	1.2	18.6	10.2	1.0	1.0	0.2
Others	23.3	17.0	23.7	70.0	45.0	-
Total production (kg)	19285	3137	9152	10643	3635	15344
Yield (kg/ha/yr)	(29.2)	(4.8)	(13.9)	(32.3)	(11.0)	(46.5)
Seed stocked (individuals/ha/yr)						
Major carps	19	182	-	-	-	1070
C. carpio	1030	672	-	-	-	303

On the other hand, tilapia seems to have been influenced by the goby *Glossogobius sp.* which entered the reservoir in 1973 through the link canal from the nearby Meenkara reservoir and developed a significant fishery in the next eight years. While the goby contributed an average of 28.9 per cent to the total catch, tilapia plunged to an average of 45 per cent from 60.1 per cent in 1969-1973. Interestingly enough, *Puntius sp.* rose to 42.61 per cent in 1977-1981 from a low 6.5 per cent in 1973-1977, parallel to that of *Glossogobius* (Table 5).

After a severe drought that left the reservoir completely dry in 1981-1982, the species composition in the reservoir changed significantly. Miscellaneous varieties (details not available) dominated the reservoir during the next four years until tilapia regained its supremacy in 1988-1990.

3.4.6 Meenkara Reservoir

The contribution of tilapia to the total catch in this 259-ha reservoir did not fluctuate very widely between 1966-1990, with the percentage ranging from 36.72 for 1981-1983 to 57.34 in 1966-1972. At the same time, the major carps increased from 0.5 to 35.7 per cent from 1973 to 1990, supported by regular stocking (Table 6). From 1988-1990, both tilapia and the major carps performed well, raising the yield to 38.43 kg/ha/yr, the highest ever during the 1966-1990 period. *Puntius curmuka* showed a definite decline during this same period.

Table 6
Trend and composition of fish yield, Meenkara reservoir, Kerala.

Species	Percentage contribution to the total catches						
	1966–72	1973–75	1975–77	1977–79	1981–83	1986–88	1988–90
L. rohita	2.01	0.1	0.4	1.1	0.27	0.12	0.19
C. catla	1.49	1.0	0.15	–	–	9.83	30.84
C. mrigala	3.77	–	–	–	0.75	14.00	4.72
Major carps (Total)	7.27	1.1	0.55	1.1	1.02	23.50	35.70
C. carpio	6.17	0.75	4.99	9.97	3.4	9.83	1.49
P. curmuka	12.95	23.38	16.91	6.67	23.12	5.82	1.55
O. mossambicus	57.34	53.56	48.90	40.06	36.72	52.0	46.62
Total production (kg)	42935	11741	10920	5606	4390	19415	47374
Yield (kg/ha/yr)	(9.96)	(9.53)	(8.86)	(4.55)	(4.32)	(15.76)	(38.43)
Tilapia (kg/ha/yr)	7.99	5.10	4.33	1.82	1.31	18.19	16.38
Major carps (kg/ha/yr)	1.01	0.15	0.05	0.05	–	3.77	13.72
Seed stocked (individuals/ha/yr)	176	–	–	166	–	94	258

3.4.7 Peechi Reservoir

Tilapia and the major carps showed similar yields from 1965-1989 in this 1,263-ha reservoir (Table 7). The tilapia population showed a rapid decline in relative (57.4 to 10.6 per cent) as well as in absolute (4.8 to 0.76 kg/ha/yr) terms from 1985-1987 to 1989-1990. In contrast, *Puntius sp.* and *L. fimbriatus* made steady contributions to total production during the same period.

Table 7
Trend and composition of fish yield, Peechi reservoir, Kerala

Species	Percentage contribution to the total catches					
	1966-67	1970-75	1975-80	1985-87	1987-89	1989-90
L. rohita	10	-	-	1.9	2.6	4.8
C. catla	0.5	-	-	9.8	26.3	57.3
C. mrigala	1.5	6.4	-	11.2	12.9	95.0
Major carps (Total)	2.0	6.4	-	22.9	41.8	71.6
L. fimbriatus	11.6	3.4	2.5	1.0	1.9	3.2
Puntius sp.	-	5.7	7.5	9.4	13.2	7.8
O. mossambicus	44.7	66.2	69.9	57.4	35.0	10.6
Others	41.8	18.3	19.84	9.2	8.0	6.8
Total production (kg)	2038.5	3756	5520	21017	21262	17943
Yield (kg/ha/yr)	1.61	0.6	0.9	8.3	8.41	7.10
O. mossambicus (kg/ha/yr)	0.7	0.4	0.6	4.8	2.95	0.76
Major carps (kg/ha/yr)	Neglible	0.04	-	1.9	3.5	5.08
Stocking seed (No./ha/yr)	-	-	-	184	1016	58

3.4.8 Malampuzha Reservoir

This reservoir is relatively large at 2,213 ha. The *O. mossambicus* it produces is known for its fast growth, large size, and good taste. Inquiries at the landing site revealed that tilapia weighing up to 2.5 kg apiece were quite common in the reservoir until 1969. At that time, average weight was reported to be 1.5-1.75 kg. At present, the average weight is around 500-700 g and fish weighing 1.5 kg are rare in the catches. It is not possible, however, to quantify the decline in growth in absolute terms in view of the absence of documentation on the size structure of the catches over the years. In general, tilapia yield has varied only slightly from 1.29 kg/ha/yr in 1977-1981 to 1.73 kg/ha/yr in 1971-1976 except for an exceptionally low figure of 0.24 kg/ha/yr in 1982-1986 (Table 8).

Table 8
Trend and composition of fish yield, Malampuzha reservoir, Kerala.

Species	Percentage contribution to the total catches				Seed stocking
	1971–76	1977–81	1982–86	1986–89	(1986–89)
L. rohita	0.1	0.1	0.7	4.3	24
C. catla	1.0	0.2	4.1	7.3	76
C. mrigala	0.4	0.1	4.4	8.3	144
Major carps (Total)	1.5	0.4	9.2	19.9	244
P. curmuka	30.1	29.3	61.9	30.2	–
P. curmuka +	35.0	41.8	78.0	39.2	*(C. carpio)* 851
Misc. carps					*(H. molitrix)* 32
O. mossambicus	43.8	33.7	5.1	30.9	1300/ha/yr
Other fishes	19.7	24.0	7.2	11.0	
Total production (kg)	43590	33754	40454	35137	
Yield (kg/ha/yr)	3.94	3.81	4.57	5.29	
Major carps (kg/ha/yr)	0.06	0.02	0.42	1.0	
O. mossambicus (kg/ha/yr)	1.73	1.29	0.24	1.63	
P. curmuka (kg/ha/yr)	1.18	1.12	2.83	1.60	

3.4.9 Sondur Reservoir

This 2,400-ha reservoir, situated in the Raipur district of Madhya Pradesh, was created in 1987 on the Sondur river and has been utilized for fisheries development since 1989. *O. mossambicus* gained accidental entry into the reservoir in the same year from the Dandakaranya culture waters of Orissa and formed a major fishery in 1989 itself. Details on fish yield from the reservoir from 1989-1991 are shown in Table 9.

Table 9
Fish yields from Sondur reservoir, Madhya Pradesh.

Fish groups	% Contribution		Yield (kg/ha)	
	1989-1990	1990-1991	1989-1990	1990-1991
Major carps > 1 kg	1.4	2.8	0.23	0.30
Major carps < 1 kg				
+ large catfishes	4.0	2.4	0.67	0.25
Small catfishes	8.7	9.6	1.50	1.00
Carp minnows	65.9	45.6	11.00	4.90
Carps, Total	69.5	49.6	11.60	5.20
O. mossambicus	20.0	39.6	3.30	4.28
Total production (kg)	24,954	15,856		
Total yield (kg/ha)			16.70	10.67

Data Source: Deputy Director of Fisheries, Government of Madhya Pradesh, Raipur.

The contribution of tilapia to total catch and its yield per hectare both increased substantially with the decrease in yields of the carp minnows and small catfishes. The overall yield of carps was reduced by half from 11.6 kg/ha in 1989-1990 to 5.2 kg/ha in 1990-1991. Yield from the major carps above one kg remained steady, however.

3.4.10 Discussion: Performance of Tilapia in Indian Reservoirs

A perusal of the data on tilapia performance in Tamil Nadu reservoirs shows some interesting trends. As shown in Table 10, higher yields were observed in smaller reservoirs up to 200 ha in area, with the yield decreasing as a function of area. The largest reservoir giving a significant yield of tilapia (34.8 kg/ha) was Krishnagiri with an area of 1,280 ha, followed by the 3,263-ha Poondi reservoir with a tilapia yield of 15.9 kg/ha. Except for these two reservoirs, all the other major reservoirs (above 1,000 ha) have either negligible populations of tilapia or no tilapia at all. The highest yield from any tilapia-dominated reservoir was obtained from Pambar, a 100-ha reservoir, which yielded 633 kg/ha in 1983-84 with a species composition of tilapia, 77 per cent; major carps, 18.4 per cent; and *P. sarana*, 2.4 per cent.

In Table 11, the reservoirs are classified according to the percentage contribution of *O. mossambicus*. The yield rate was substantially higher in reservoirs which had more than 75 per cent of tilapia in the harvest. From the above observations, it was difficult to arrive at any definite conclusions regarding the effect of tilapia on the major carps or *vice-versa*. The yield of the major carps did not show any definite trend in these reservoirs though their highest yield rate was obtained from reservoirs having less than 25 per cent tilapia in the catches. It is significant that all these reservoirs were adequately stocked with major carp seed and yet, the major carp yield was restricted to less than 12.25 kg/ha/yr. Even the four reservoirs having no tilapia had low yields of major carps (0.6-4.0 kg/ha) in spite of heavy stocking (343-890 individuals/ha).

Table 11

Reservoirs categorized on the basis of percentage contribution of O. mossambicus (1989-90).

Contribution (%) of tilapia to total catch	Number of reservoirs in each category	Average area (ha)	Average yield (kg/ha/yr)	Average number of major carp seed stocked (individuals/ha)	Average contribution of major carps (kg/ha/yr)
above 75	9	160 (74-657)	79.3 (50-291)	463 (133-1615)	7.84
50 -75	12	426 (50-1280)	44.5 (4-346)	453 (164-2667)	6.51
25 - 50	14	672 (31-5760)	28.9 (3-358)	363 (290-2399)	6.77
2 - 25	7	1995 (196-7265)	25.3 (5-98)	327 (213-2073)	12.25
0 - 2	9	2502.1 (388-15540)	8.1 (14-57)	352 (288-888)	2.56

Data source: Tamil Nadu Fisheries Department.

For none of these reservoirs have data been recorded regularly on the catch structure of either tilapia or other species contributing to the fishery. Hence, it is difficult to arrive at any conclusion on growth reduction related to age or fluctuation in population density of fishes from these waters. Experiences of fishermen and officials are the only clues for any such conclusion. *Catla* is reported to grow to 8-10 kg in three years in the Chulliar reservoir, in which tilapia maintained a population contributing 40-60 per cent of the total catch during most of the years. In Malampuzha, *catla* of 15 kg are not rare in the catches. *P. curmuka* was reported to grow to one kg in this reservoir during the period 1960-70, but the maximum size now reported is about 250 g. *Labeo calbasu* weighing more than one kg and *L. rohita* above four kg are also common in the catch.

3.5 In Cages and Pens

The cage culture of *O. mossambicus* was first undertaken in India about 23 years ago on an experimental basis. A density of 150 fingerlings per sq m gave the highest production of 31 kg/sq m (16.38 mt/ha/month). The growth rate was 41 g (from six to 47 g) in 99 days of culture with a survival rate of 88.8 per cent.

Recently, some pen culture experiments were conducted in a 12-ha *bheri* in West Bengal (CICFRI Annual Report, 1990-91). Pens were erected with split bamboo,and had an effective area of 10.2 sq m (3 x 3.4 m). Each pen was stocked with *O. niloticus*, *O. mossambicus* and *C. carpio* at a ratio of 1:2:1 at a combined density of 40,000 individuals/ha. The results of the five-month rearing trials are shown in Table 12 below.

Table 12

Production of *Oreochromis* spp. and *C. carpio* in pens installed in *bheries*

Species	Initial wt (g)	Final measurements, length/ wt	
		Pen I	Pen II
O. mossambicus	8.4	127 mm/31.4 g	128 mm/32.5 g
O. niloticus	19.5	148 mm/65.6 g	147 mm/64.5 g
C. carpio	38.8	164 mm/81.0 g	169 mm/89.2 g

4. GENERAL CONSIDERATIONS

One of the important factors determining the success of introduction of exotic fishes is their feeding habits. As none of the Indian cultivable carps feeds on Myxophyceae (like *Microcystis aeruginosa*), tilapia will be a welcome addition to reservoirs dominated by blue-greens (e.g, Rihand). Tilapia is known to digest and assimilate this abundant algal resource which, as indicated by Moriarty (1973), may be the primary reason for very high yields of tilapia in shallow tropical lakes. It is known that in certain alkaline lakes, *O. niloticus* grows to exceptionally large sizes. It is suspected that the high sodium to calcium ratio in such lakes breaks down the cell walls of the blue-green algae, allowing its digestion by the fish.

On the other hand, dams stocked with weed-eating tilapia have shown poor results in Tanzania. Moyle (1976) reported that since the introduction of *O. mossambicus* and *T. zillii* for weed and insect control in California, they have become abundant and widespread and have affected the relative abundance of the different fish and zooplankton species. The introduction and proliferation of macrophyte-feeding tilapias, especially of *T. rendalli*, have seriously perturbed the ecology of certain water-bodies. For example, it has devastated, in three years, nearly 3,000 ha of *Ceratophyllum* and *Nymphaea* beds and, as a result, caused the almost total disappearance of a valuable indigenous fish, *Paretopus petite,* in Lake Kyle of Zambia (Lamarque *et al.,* 1975).

Sreenivasan (1967) has studied the influence of tilapia on other dominant species of fishes in Madras waters. He found that in ponds such as the West Moats in Tanjore district of Tamil Nadu, tilapia did not influence carp growth. He, however, observed that in Ayyakulam pond, the growth of *Chanos chanos* was restricted by tilapia to less than 100 g instead of the usual 500 g in many waters of Tamil Nadu. However, Sreenivasan (1967) could not establish the characteristics of the water-bodies that may be regarded as conducive to tilapia populations. Many long-distance transplantations of tilapias to a different climatic zone or to different altitudes have also proven to be failures, like those of *S. macrochir, S. andersonii, S. spilurus niger,* and *T. rendalli* in certain cold regions of South Africa. Studies reveal that tilapias have established themselves and formed stable populations mostly in environments characterized by suitable temperature conditions and a vacant niche.

In India, as it has been shown the establishment of tilapia could generate unfavorable conditions, as in the following:

(i) Initial growth of population followed by spontaneous regression with failures resulting from competition with local species or due to environmental conditions, e.g., South Indian reservoirs like Vaigai, Peechi, etc;

(ii) Excessive reproduction leading to overpopulation and dwarfing, e.g., some reservoirs in South India where, owing to these traits, tilapia has supplanted the native ichthyofauna; and

(iii) Disappointing results due to continuous reproduction (overpopulation and dwarfing) in tropical environments and to slow growth and winter mortalities in regions with a distinct cold season. The difference in the performance of tilapia in north and south India may be the reason behind the recent failure of an attempt to transplant a consignment of tilapia into the Baghla reservoir in Uttar Pradesh.

Notwithstanding the negative features of tilapia introduction, as mentioned above, the fish portrays many positive characteristics. Studies have indicated that in polyculture systems containing catfish and tilapia, production of tilapia is good and catfish production is also accelerated without changing the food application. One of the

greatest advantages of tilapias is that they feed low in the food web and graze on phytoplankton, filamentous algae, zooplankton, and detritus. While they do well on commercial feed, they do equally well in systems having animal manure. All-male tilapia hybrid culture in cages have given yields higher than 50,000 lbs/acre/yr in temperate countries. In the Philippines, farming of *O. niloticus* with pigs or poultry has produced outstanding results. Perhaps, the most difficult problem associated with tilapia culture is its uncontrolled reproduction; it is sexually precocious and can begin to reproduce when less than 100 g in size.

The debate on the introduction of tilapia into Indian waters mainly centers around the following issues: (i) the possibility of affecting or even displacing the native ichthyofauna; (ii) the yield potential of the introduced species; and (iii) consumer preference, taste-wise and cost-wise. These are discussed below.

(i) **Danger to Native Fauna:** Tilapia is known to be a prolific breeder and it exhibits considerable plasticity in feeding behavior. Moriarty and Moriarty (1973) have demonstrated that *O. niloticus* can assimilate up to 80 per cent of carbon ingested through algae like *Microcystis, Anabaena*, and *Nitzchia*. *O. mossambicus* has been shown to consume vegetable debris and macrophytes (Bruton and Boltt, 1975; Man and Hodgkiss, 1977). It has also been observed that *O. mossambicus* and *O. niloticus* have a wider omnivore food spectrum compared to many other tilapia species. Philippart and Ruwet (1982) presumed that in feeding habits, the general qualitative characteristics of the tilapia depend on:

* The type of organisms present, which in turn depends on the limnological and physico-chemical characteristics of the waterbody;

* The accessibility to food organisms according to their local distribution; and

* The presence of competing species, which forces each species to restrict its food spectrum and to exploit its specializations.

In the sewage-fed wetlands of Calcutta, adult *O. niloticus* was observed to feed chiefly on phytoplankton, which constitute up to 96.4-99.2 per cent of the diet. Bacillariophyceae constituted 17.8-65.3 per cent; Chlorophyceae, 11.3-44.4 per cent; and Myxophyceae, 23.4-41.0 per cent, with wide variations exhibited from month to month, more or less oscillating along with the food availability in the environment (CICFRI Annual Report, 1990-91). The fecundity ranged from 290 to 1,660 depending on the size (170 mm/80 g to 180 mm/115 g).

Indian reservoirs generally harbor a high density of Myxophyceae, Bacillariophyceae, and Chlorophyceae in that order. If the large reservoirs are excluded, the depth of inland waterbodies is also within 10 m (i.e., 6-10 m in case of small reservoirs and 2-5 m in case of wetlands, tanks, and ponds). The temperature variation is limited mostly to 20-30°C. Such an environment, by all biological standards, is ideally suited to tilapia as is also the case with most of the commercially important native carps. Obviously, there is bound to be a competition between carp and tilapia species.

Therefore, a possible competition for domination between the tilapia and the major carps is ultimately decided by recruitment success. Tilapia, being able to breed in confined waters, has an obvious advantage over the major carps.

(ii) **Influence on Yields:** Tilapia entered the Indian scene when inland waters made negligible contributions to total fish production and when fishery science was in its infancy with no suitable technology to harvest the productive potential of the water-bodies. Over the years, tilapia has become a controversial species mainly on two counts:

* In many of the waters, its overpopulation along with reduced growth rate has led to a decline in yield; and

* The evolution and advancement of fish husbandry technology ensure a high yield with the endemic fauna and the exotic carps that do not breed in confined waters.

It is relevant to mention here that the auto-stocked Keetham reservoir in Uttar Pradesh could give a harvest of 533 kg/ha/yr, with the major contribution coming from carps. Similarly, Aliyar in Tamil Nadu could achieve over 220 kg/ha/yr, of which 90 per cent was constituted by carps. Besides, all the tilapia-dominated reservoirs do not give high yields and the waterbodies having high water level fluctuations fail to establish a good tilapia fishery. Furthermore, tilapia production in many South Indian reservoirs has shown an erratic trend; initial high production was followed by a relapse. Hence, it is unwise to depend chiefly on tilapia to enhance yield from the culture-based capture fisheries, especially so when carps are preferred over tilapia in many parts of the country. It would be more logical to depend on a multispecies fishery not allowing tilapia to monopolize the environment, both in terms of high yield and market demand.

(iii) **Consumer Preference**: Tilapia is basically known as a species affordable by the poor. This is true in the context of West Bengal and the tribal belts of Orissa and Tamil Nadu. The Palghat and Trichur districts of Kerala do have an obvious preference for *O. mossambicus* over carps. Even if given at equal prices, the fishermen around Peechi reservoir prefer tilapia. The current market price for tilapia ranges from Rs. 18-30 for *O. mossambicus* (25-200 g) and Rs. 35-50 for *O. niloticus* (200-800 g) in West Bengal; Rs. 35-50 in Palghat and Trichur districts (Kerala); Rs. 15-20 in Tamil Nadu; and Rs. 30-35 in Madras for the golden variety raised in the farm of VCDI, Madras. The Government-sponsored retail outlets in almost all these states have fixed the price of tilapia at half the rate of carps. This amounts to Rs. 9 in Kerala, Rs. 6 in Tamil Nadu, and Rs. 9 in West Bengal.

5. OPTIONS FOR THE FUTURE

The production of all-male hybrids through hormone treatment and their intensive culture are being increasingly practised in several countries. Interest seems to be growing in India about the unconventional approach in tilapia production. The technology has proven to be economically viable and some private firms in India have already established such production systems with considerable success. Taking into account the possible future impacts of such systems in India, it is felt that tilapia culture using all-male hybrids is worth encouraging as it is likely to give a tremendous boost to the inland fish production in the country, especially as the species has a growing consumer acceptance.

Tilapias have many attributes which make them suitable for culture in small seasonal reservoirs which are cropped annually. North Indian reservoirs have a well-marked cold season which perhaps acts as a factor limiting the prolific breeding observed in some of the peninsular ponds and tanks. This climatic barrier might have prevented the fish from establishing itself as a self-sustaining population in waterbodies of the Gangetic plains. This, at least to some extent, should eliminate the fear of tilapia invading the Gangetic system and threatening the Indian major carps in the event of its introduction in lentic waters of the Gangetic plains.

O. mossambicus, regarded generally as a pest in India, has been reared in *bheries* of West Bengal for the last three decades. These waterbodies are subject to overflooding with every possibility of the species getting entry into the estuary. However, this has not happened and the fish has not been able to breed or establish itself in the estuary, perhaps on account of some ecological barrier.

Unlike *O. mossambicus*, *O. niloticus* commands a good market preference even in West Bengal, where the preference for Indian major carps is well-known. There are many areas in the country where there is no market preference for carps. For instance, in the north and northwest, catfishes are preferred over carps. In Kerala, tilapia is preferred to carps. *O. niloticus*, already a popular culture material in the *bheries,* is emerging as a promising candidate species for culture in such areas where it has a potential market.

Irrespective of whether tilapia affects the endemic fauna or not, the species *O. mossambicus* has taken a firm base in the culture and small and confined culture-based systems of India. It is now practically impossible to get rid of the species.

It will, therefore, be wise to make the best use of the species to enhance yield in combination with the native fauna. The following options are available for the purpose:

(i) Utilize the technology of monosex culture to obtain a better yield. Tilapia hybrids already demonstrated impressive growth potential using a wide variety of commercial and agricultural products as diets. All-male tilapia culture has to be accomplished on a commercial scale.

(ii) Search for a better species of *Oreochromis* to substitute and replace *O. mossambicus*. *O. niloticus* and *T. zillii* are species worth considering.

(iii) Adopt cage/pen culture for tilapia, which would prevent excessive breeding and overpopulation. Cage culture will be an additional activity in reservoir management that could result in substantial increases in yield. Reports of very high yields from pen culture of tilapia are available; for example, from a four-ha pen, a total harvest of 200 t of tilapia was obtained.

(iv) Stock the reservoirs with larger-sized carp fingerlings at high density (100-150 mm and above) to enhance their survival and prevent domination of tilapia in reservoirs.

(v) Explore the possibility of tilapia culture in some aberrant ecotopes like sodic and saline soil types in semi-arid zones of the country.

(vi) Utilize waste waters and the heated effluents from thermal discharge sites for tilapia culture. This will open up new vistas for grow-out of this fish in waters receiving heated effluents which is of significance in the wake of a number of thermal power plants getting established in the country.

(vii) Improve the technique of controlling overcrowding of tilapia by introducing a suitable predator species like *Lates calcarifer* or murrels and standardizing the units of population. Some studies in this direction have been made in CICFRI.

Perhaps one of the reasons for the present underutilization of tilapia in India is the lack of a strain developed genetically for adaptation to different aquaculture situations. As a result, tilapia grown in new ecosystems are very similar to their wild progenitors. Studies on these lines would be worthwhile for proper utilization of the species which has been likened to chicken - because it can be mass-produced from eggs, intensively farmed in backyards, and can convert plant products into animal protein at a very efficient and economic rate.

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THE ROLE OF TILAPIA IN CAPTURE AND CULTURE-ENHANCED FISHERIES IN INDONESIA

by

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1. INTRODUCTION

Tilapia is an exotic species in Indonesia. There are two main species known in the country, namely: *Oreochromis mossambicus* and *Oreochromis niloticus*, either black or red hybrid. Tilapia has become a preferred species in Indonesia since it grows fast, reproduces easily, is disease-resistant, and tastes good.

The Indonesian name of *O. mossambicus* is *mujair*, after the farmer, Mr. Mujahir, who found it accidentally in the Blitar area in East Java. In 1980, a red *O. mossambicus* (*mujarah*) appeared. The fish is prolific, easy to culture either in freshwater or brackishwater, and is now present in many lakes, reservoirs, and swamps in Indonesia. The species is becoming increasingly more important as a source of animal protein, particularly for low-income populations.

O. niloticus was introduced into Bogor from Taiwan in 1969 (Hardjamulia, 1977). At that time, it was felt that the plankton, which was abundant in the country's inland waters, was not efficiently utilized by local species such as *Helostoma temminckii* and *Trichogaster trichopterus*, and that *O. niloticus*, a plankton feeder, could serve that purpose. *O. niloticus* is now present in all provinces of Indonesia, both in culture and in lakes and reservoirs. It can be found, for example, in Lake Tondano in North Sulawesi, Jatiluhur reservoir in West Java, and in the natural lake, Rawa Pening, in Central Java.

Red tilapia is a hybrid which appeared in West Java in 1970. Its origin is unknown. Another red tilapia (*nila merah*) was introduced into Bogor from the Philippines in 1980. It is a hybrid of a mutant-orange female *O. mossambicus* and a normal-colored grey female *O. niloticus* (Fitzgerald, 1979). The growth rates and production of various species - local, Philippine, and hybrid red tilapias - are the same (Yunus *et al.*, 1987).

Intensive fish culture started in 1985 in floating cages in the new man-made lakes of Saguling and Cirata. Since then, this method has been introduced in other reservoirs in Central Java, East Java, North Sumatera, and North Sulawesi. While common carp is the major species cultured in cages, the red tilapia (*nila merah*) is now increasingly grown in cages in view of its food conversion efficiency.

2. TILAPIA AND THE INLAND CAPTURE FISHERIES OF INDONESIA

2.1 The Resource Base

Indonesia has some 55 million ha of open waters including lakes, reservoirs, rivers, and swamps (Ilyas *et al.*, 1990). The reservoirs, which are either single or multipurpose, range in area from <100 ha to 9,000 ha. In addition to those that are existing at present, some 128 other reservoirs are planned for construction, as follows: Sumatera, 32; Java, 59; Bali, 4; West Nusa Tenggara, 12; East Nusa Tenggara, 5; Kalimantan, 5; and Sulawesi, 9 (Directorate Sungai, 1984). These reservoirs offer an opportunity for fisheries development in addition to their primary uses for irrigation and flood control, among others.

2.2 Production Performance

In 1988, Indonesia produced a total of 2.88 million mt of fish, of which some 2.17 million mt came from marine fish capture and the balance of around 710,000 mt came from inland fisheries. Of this volume, around 280,000 mt were caught from the open waters and the balance of about 430,000 mt, from culture in brackish- and freshwater ponds, cages, and rice fields (DGF, 1990).

Of the about 710,000 mt of fish produced from the country's inland waters, tilapia contributed about 57,000 mt, representing around eight per cent of total inland fish production. Out of this volume, approximately 8,000 mt, or about 13 per cent, were caught from the open waters and the balance of roughly 49,000 mt or 87 per cent came from aquaculture. Since 1981, tilapia production has been on the rise, with a significant increase noted during the 1987/88 period when production rose from 43,041 mt in 1987 to 57,245 mt in 1988 (Table 1).

Table 1
Tilapia production in Indonesia, 1981-1988
(Directorate General of Fisheries, 1990)

Year	Production (mt)		
	Capture	Culture	Total
1981	6929	26583	33512
1982	8269	25825	34094
1983	7059	36273	43332
1984	7530	38089	45619
1985	6767	32237	39004
1986	7244	36541	43785
1987	7982	35059	43041
1988	7980	49265	57245

In terms of contribution to the species composition of the catch, the tilapias ranked ninth among 14 major freshwater fish species in 1988 (Table 2). In the new Saguling reservoir, *O. niloticus* ranked fifth among nine species represented in the catch (Table 3). In Bali, tilapia represented 47 per cent of total fish yield and contributed about Rp. 5.6 billion or USD2.94 million (at an exchange rate of USD1 = Rp. 1,900) to the economy (Dinas Perikanan Tingkat I Bali, 1989).

Table 2
Species composition of fish caught in inland waters, 1988
(Directorate General of Fisheries, 1989)

Fish species		Percentage composition	Rank
Snakehead *(Ophicephalus* sp.)		11.44	1
Snakeskin gouramy *(Trichogaster pectoralis)*		8.71	2
Java barb *(Puntius javanicus)*		8.05	3
Glass catfish *(Cryptopterus* sp.)		6.49	4
Kissing gouramy *(Helostoma temminckii)*		5.20	5
Catfish *(Pangasius* spp, *Wallago* spp., *Macrones* spp.)		4.92	6
Asian barb *(Puntius* spp.)		3.92	7
Indonesian snakehead *(Ophicephalus micropeltus)*		3.71	8
Tilapia *(Oreochromis mossambicus, O. niloticus)*		2.84	9
Knife fish *(Notopterus* spp.)		1.86	10
Hoven carp *(Leptobarbus hoeveni)*		1.81	11
Common carp *(Cyprinus carpio)*		1.53	12
Sleeper gobys *(Oxyeleotris marmoratus)*		0.65	13
River eel *(Anguilla* spp.)		0.29	14
Other species:	fish	31.62	15
	crustaceans	5.68	
	molluscs	0.53	
	aquatic animals	0.60	

Table 3
Species composition (%) in Saguling reservoir *(Krismono et.al.*, 1987)

Fish species	Percentage composition	Rank
Hampala macrolepidota (hampal)	52.73	1
Osteochilus hasselti (nilem)	26.34	2
Puntius bramoides (genggehek)	4.99	3
Oreochromis niloticus (nila)	4.29	4
Cyprinus carpio (mas)	4.24	5
Anabas testudineus (betok)	3.59	6
Puntius gonionotus (tawes)	3.44	7
Trichogaster trichopterus (sepat)	0.31	8
Ophicephalus striatus (gabus)	0.31	9

2.3 Stocking of Tilapia in Lakes and Reservoirs

Tilapia has been stocked in a number of lakes and reservoirs in Indonesia as a means of enhancing fish production in these waterbodies (Table 4; Fig. 1). As tilapia grows well and reproduces easily in open waters, it is usually able to establish populations in reservoirs in a relatively short time. Both *O. mossambicus* and *O. niloticus* have been stocked in lakes and reservoirs although with varying success.

O. mossambicus has been stocked in Lake Toba in North Sumatera, Lake Ranau in South Sumatera, Lake Tondano in North Sulawesi, and in brackishwater swamps. In Lake Toba, tilapia is an economically important species and contributes 86 per cent to the total production of that lake. Its introduction, however, has resulted in the decline of some indigenous species like the "*ikan Batak*" (*Lissochilus sp.*) which is used for

Table 4
Introduction and stocking of tilapia in lakes and reservoirs in Indonesia

Waterbody	Year of introduction/stocking	
	O. mossambicus	*O. niloticus*
Reservoirs		
West Java:		
Jatiluhur	1965	1972–1987
Saguling	1985	1987
Cirata	1987	1987
Central Java:		
Rawapening	*	*
Wonogiri	*	*
Kedungombo	*	*
Wadaslintang	*	*
East Java:		
Selorejo	1970	1974
Karangkates	*	*
Lakes		
North Sumatera:		
Toba	*	*
West Sumatera:		
Singkarak	*	*
South Sumatera:		
Ranau	*	*
Central Sulawesi:		
Lindu	1951	*
Poso	*	*
North Sulawesi:		
Moat	*	*
Limboto	1944	*
Tondano	1951	1971
Irian Jaya:		
Sentani	*	*

* Year of introduction unknown.

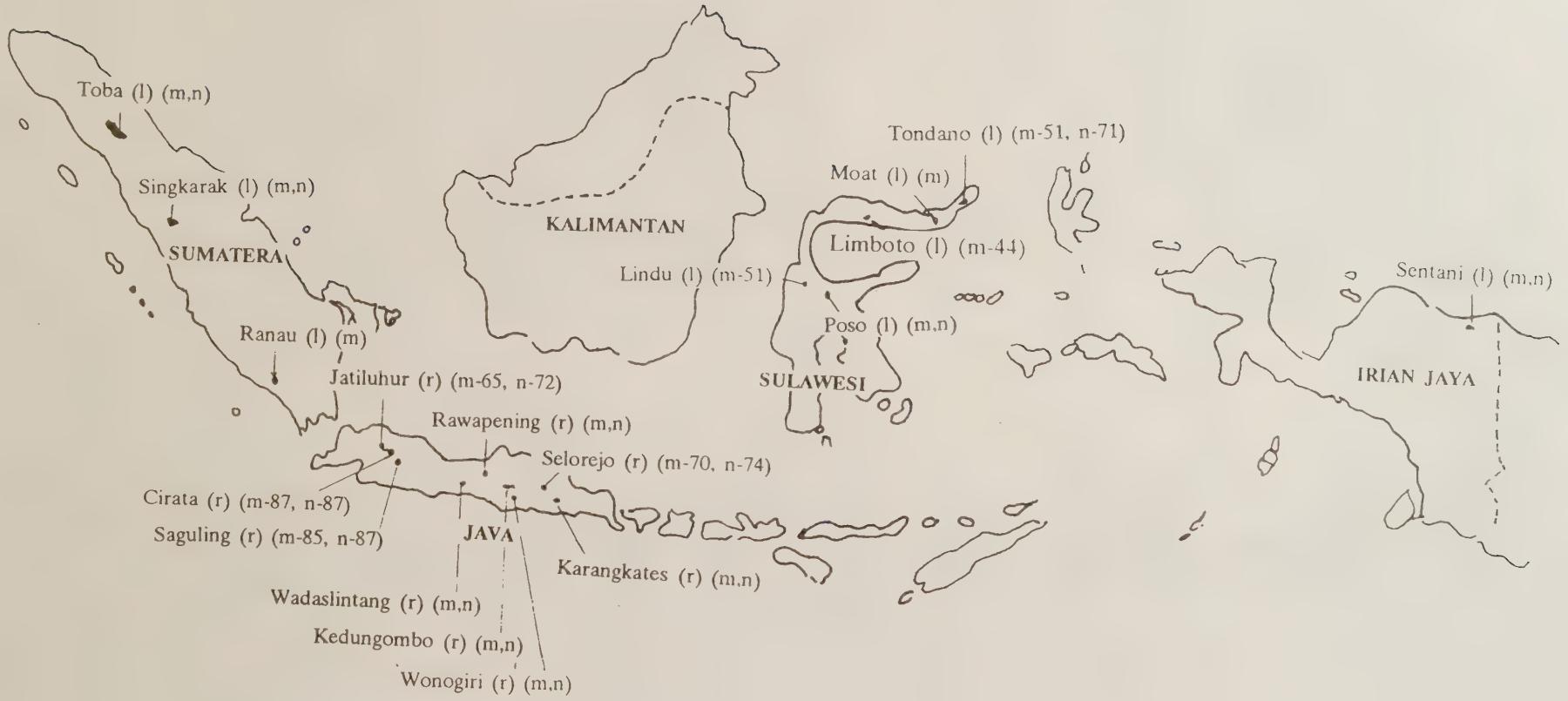

Fig. 1. Distribution of *O. mossambicus* (m) and *O. niloticus* (n), their date of stocking (m or n, year) in lakes (l) and reservoirs (r) of Indonesia.

traditional functions like weddings and religious parties. The decline in local fish populations is thought to be due to intense competition with tilapia for food. *Cyprinus carpio* (common carp) has been stocked in Lake Toba in large numbers but its production has been low, at 1.6-13 per cent of total production compared to at least 87 per cent for tilapia (Kartamihardja, 1987).

In some new reservoirs, *O. mossambicus* established populations from fish stocks already present in the rivers and other waterbodies, as in Selorejo, Saguling, and Cirata. *O. mossambicus* was also stocked in Lake Paniai in Irian Jaya, but was not successful, perhaps due to the high altitude (1742 m above sea level) and the low water temperature (15-24°C) which may not be favorable to the fish.

O. niloticus, which was introduced in Indonesia in 1969, is more highly valued than *O. mossambicus* because of its bigger size, better taste, and higher selling price, but is less successful in establishing populations in reservoirs (Table 5). Suseno *et al.* (1978) reported problems with stock purity of *O. niloticus* due to the ease of crossbreeding in nature (Table 6). Although the hybrids of male *O. niloticus* x female *O. mossambicus* grew faster than the parent species, stocking programs using these hybrids were largely unsuccessful (Suseno, 1983). It is only in Jatiluhur reservoir where the stocking of *O. niloticus* showed some success, and probably as a result of sustained stocking from 1972 to 1987 (Tables 7 and 8). It is possible that *O. niloticus* was not successful in establishing populations in the other reservoirs where it was introduced due to low numbers stocked and/or to the lack of continuity of the stocking program.

Table 5
Percentage contribution of *O. niloticus* and *O.mossambicus* to the total fish production in some reservoirs and lakes in Indonesia

Lake/Reservoir	Percentage contribution to total yield	
	O. niloticus	*O.mossambicus*
Jatiluhur	3.6	*
Saguling	*	*
Wonogiri	*	*
Toba	*	96.0
Karangkates	10.6	86.0
Selorejo	6.0	90.0
Bening	*	79.2

* = small percentage, negligible.

Table 6
Percentage of species purity of *O. niloticus* in West Java

Location	Date of testing	Number of samples	Pure	%	Crossed	%
Cisaat	August 1976	33	11	33.3	22	66.7
	September 1976	21	5	23.8	16	26.2
	November 1977	33	1	3.0	32	97.0
	December 1977	33	0	0.0	33	100.0
	January 1978	33	1	3.0	32	97.0
	January 1979	26	6	23.1	20	77.0
Cianjur	August 1976	33	18	54.5	15	46.0
Purwakarta	August 1976	33	26	28.8	7	21.2

Table 7
Stocking density and numbers stocked *O. niloticus* in Jatiluhur reservoir, 1972 – 1981 (from Krismono, 1989)

Year	Stocking rate	Number stocked
1972	25	5,000
1973	150	26,000
1974	100	20,000
1975	*	*
1976	350	18,000
1977	550	25,000
1978	350	10,000
1979	800	16,000
1980	500	10,000
1981	695	12,300
1987	*	*

* no data available.

Table 8
Total fish yield (kg) and percentage contribution in *O. niloticus* in Jatiluhur reservoir (from Kartamihadja and Hardjamulia, 1983).

Year	Total yield (kg)	% of total yield
1972	108,300	
1973	153,100	
1974	99,100	
1975	95,500	
1976	81,300	0.2
1977	97,500	0.4
1978	104,100	1.9
1979	178,900	2.7
1980	270,100	2.8
1981	282,600	4.5
1982	306,900	3.7
1984	249,100	4.1
1986	451,900	3.0

2.4 Natural Food Availability and Feeding Habits of Tilapias and Other Fish in Reservoirs

Plankton and detritus constitute the most important food items in the diet of fish in Indonesian lakes and reservoirs. The common fish species are mostly omnivores which feed on detritus, macrophytes, algae, insects, and rotifers, among others (Table 9).

Table 9
Food preferences of the common fish of reservoirs and lakes in Indonesia

Species	Family	Feeding habit
Hampala macrolepidota (hampal)	*Cyprinidae*	P
Puntius gonionotus (tawes)	*Cyprinidae*	H
Osteochilus hasselti (nilem)	*Cyprinidae*	E
Puntius binotatus (beunteur)	*Cyprinidae*	O
Cyprinus carpio (mas)	*Cyprinidae*	O
Rasbora argyrotaenia (parai)	*Cyprinidae*	O
Oreochromis mossambicus (mujahir)	*Cyprinidae*	O
Oreochromis niloticus (nila)	*Cyprinidae*	O
Macrones nemurus (tagih)	*Bagridae*	P
Channa striatus (gabus)	*Ophiocephalidae*	P
Clarias batrachus (lele)	*Clariidae*	P
Oxyeleotris marmoratus (betutu)	*Eleotridae*	P
Anabas testudineus (betok)	*Anabantidae*	O

P - Predator
H - Herbivore
E - Epiphytic feeder
O - Omnivore

In Jatiluhur reservoir, the dominant fish species are either omnivores, feeding mostly on detritus and macrophytes, or predators/carnivores. *O. niloticus* feeds mainly on aquatic macrophytes and Dinophyceae while *Puntius gonionotus* feeds mainly on detritus; *Hampala* and *Macrones* prey on other fish (Table 10).

Table 10
The percentage composition of fish food of five fish species in Jatiluhur reservoir

Fish Food Component	*Oreochromis niloticus*	*Puntius gonionotus*	*Puntius bramoides*	*Hampala sp.*	*Macrones sp.*
Detritus	9.83	48.78	40.55	0	0
Macrophytes	50.42	33.46	5.11	0	7.93
Cyanophyceae	0.25	1.1	2.6	0	0
Chlorophyceae	0	0	0.51	0	0
Bacillariophyceae	0.07	5.1	5.71	0.42	0
Desmidiaceae	0.5	0.55	1.65	0	0
Dinophyceae	38.93	0	2.08	0	0
Cladocerans	0.05	0	13.4	8.81	0
Insects	0	2.75	18.44	23.75	37.35
Molluscs	0	8.27	10.0	0	0.58
Shrimps	0	0	0	23.04	1.64
Fish	0	0	0	33.57	39.29
Others	0	0	0	10.41	13.21

In Saguling reservoir, *O. mossambicus* feeds mainly on detritus and submerged macrophytes (40.44 per cent), followed by Bacillariophyceae (24.3 per cent) and Dinophyceae (20.1 per cent) while *P. gonionotus* feeds mostly on detritus and macrophytes (91.6 per cent) (Krismono, 1987). In Bening reservoir in East Java, the diet of *O. mossambicus* consists mainly of detritus, Dinophyceae, and Bacillariophyceae while in Lake Toba, it consists mainly of plankton (Didik, 1987).

A comparison of plankton abundance in four reservoirs in Java shows that Saguling reservoir has the highest productivity, perhaps as a result of the high nutrient load it receives from the city of Bandung (Table 11). In Saguling reservoir, 30 genera of phytoplankton and 12 genera of zooplankton have been identified, with Dinophyceae being the most dominant family (Krismono *et al.*, 1987).

Table 11
Plankton abundance (individuals/liter) in four reservoirs of Java

Species	Jatiluhur	Saguling	Cirata	Kedungombo
Phytoplankton				
Cyanophyceae	56	1,412	969	69
Dinophyceae	1	135,280	1,625	152
Bacillariophyceae	7	13,440	1,750	149
Desmidiaceae	2	5,520	1,750	-
Chlorophyceae	24	5,920	437	365
Zooplankton				
Copepoda	20	5,520	32	40
Cladocera	7	6,240	0	18
Rotifera	1	0	32	68
Protozoa	0	0	0	54

Note: The figures are averages of two samples collected in May 1987 and 1989, i.e., about two years after inundation, except for Jatiluhur where the figures represent averages over four years after inundation.

In Cirata reservoir, 48 genera of phytoplankton and 26 genera of zooplankton were identified. The phytoplankton was dominated by Chlorophyceae (19 genera), Desmidiaceae (7 genera), and Dinophyceae (3 genera); the zooplankton consisted of Rotifera (14 genera), Cladocera (4 genera), and Copepoda (3 genera) (Kartamihardja *et al.*, 1989).

Wonogiri reservoir had 44 genera of plankton, of which 32 were phytoplankton representing 81-98 per cent by number of individuals, and 12 were zooplankton. The dominant phytoplankton are the desmids *Zygnema* and *Staurastrum*, Bacillariophyceae (*Synedra* and *Diatomeae*) and Chlorophyceae (*Chlorella* and *Microspora*); other phytoplankton groups (Cyanophyceae, Dinophyceae, and Chrysophyceae) were found in small numbers. The dominant zooplankton were the copepods *Cyclops*, the cladoceran *Diaphanosoma*, and the rotifer *Keratella*, of which the copepods were most utilized by the fish (Kartamihardja *et al.*, 1989).

3. CULTURE-ENHANCED RESERVOIR FISHERIES

Cage culture of fish, mostly common carp (*C. carpio*), is practised in streams, rivers, and reservoirs in Indonesia. Bamboo cage culture was first introduced in the river Cibunut in Bandung, west Java in 1940 (Voras and Sachlan, 1955 as cited in Lukas and Cholik, 1979) and is commonly used in the country, especially in West Java. In the large rivers and streams of Kalimantan and Sumatera, local species such as *Leptobarbus hoevenii* and *Channa sp.* are used while in northern Sulawesi and south Kalimantan, common carp is used. Supplemental feeding with pellets is usually provided.

Floating cage culture was first experimented upon in Jatiluhur reservoir in 1974 but was practised on a commercial scale only starting in 1988 due to the difficult access to the culture site, which constrains the transport of fish feed and other materials. In Saguling reservoir, large-scale floating cage culture began in 1985; at present, there are over 1,300 units operated by the more than 1,500 families whose lands were flooded by the reservoir. Floating cage culture is also practised in Cirata reservoir located downstream of Saguling. Cirata has the advantage of being closer to the main road and nearer to Jakarta.

The floating cages used measure 7 x 7 x 2 m and are stocked at six kg/sq m or about 300 kg/cage. Culture period is two to three months and supplemental feeding with pellets is generally practised. Common carp is the species usually cultured. Smaller cages measuring one cu m stocked at higher densities have been introduced recently (Schmittou, 1991) and experiments using red tilapia, gouramy, and local catfish have been undertaken. The results of culture trials with red tilapia in Wonogiri and Gondang reservoirs using floating cages measuring one cu m, are shown in Table 12.

Table 12
Production performance of red tilapia raised over a three-month period in one cu m floating net cage (Krismono, 1991)

Reservoir	Stocking density	Average initial weight (g)	Average harvest (g)	Weight gain (g)	Feed conversion rate
Wonogiri					
	250	20.0	401.6	381.6	1.27
		20.0	389.2	369.2	1.31
	375	22.1	403.5	381.4	1.27
		22.7	357.6	334.9	1.44
	500	32.4	341.4	309.0	1.57
		32.0	352.2	320.2	1.47
Gondang	375	18.0	254.0	236.0	2.3
		19.0	272.0	254.0	1.8
	500	19.0	220.0	201.0	2.3
		17.0	245.0	228.0	2.1
	625	17.0	215.0	198.0	2.3
		18.0	222.0	204.0	2.1

4. PERSPECTIVES FOR FUTURE DEVELOPMENT OF TILAPIA IN CAPTURE AND CULTURE-ENHANCED FISHERIES IN INDONESIA

Tilapia, which can be produced at low cost and with minimal investment, is a suitable species for introduction/stocking in open waters and/or culture in ponds or cages, particularly in remote areas which are hardly supplied with marine fish.

In Java and in other areas where the human population density is high and where, as a result, competition among the various water users is stiff, the proper approach could be higher density culture of *O. niloticus* and red tilapia, the latter being

actually preferred because of its similarity in appearance to the expensive red snapper. Floating cage culture using red tilapia, either in freshwater or in sea water, has been intensively tested in Lampung (in Sumatra), Java, Bali, and South Sulawesi, and appears to be suitable for the more developed areas of Indonesia. *O. niloticus* has also been cultured in floating cages in Banten Bay, Pare-pare (South Sulawesi), and Sendang Biru (East Java).

Continuing efforts to improve tilapia culture have been exerted by scientists at the Central Research Institute for Fisheries (CRIFI). Recently, for example, experiments were conducted on male monosex culture of red tilapia at varying stocking densities in Depok, West Java. These trials showed that a stocking density of 15 fish (40-50 g)/cu m gave the best production after three months of culture (Yunus, 1990). In experimental ponds in Cijeruk and Bogor, the male monosex culture of *O. niloticus* gave higher daily growth rates, production gain, and benefit-cost ratios as compared to mixed sex culture (Jangkaru *et al.*, 1988). Experiments are also in progress on the use of hormones to produce all-male populations. The results of these research activities will undoubtedly be useful for the further development of tilapia culture or culture-based fisheries in the reservoirs and lakes of Indonesia.

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THE PRESENT STATUS AND EXPANSION POTENTIAL OF TILAPIA CAPTURE AND CULTURE-BASED FISHERIES IN MALAYSIA

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1. INTRODUCTION

The need to assess the use of tilapia in the fisheries management of larger inland waterbodies of the Indo-Pacific region, was highlighted in the Fourth Session of the Indo-Pacific Fishery Commission (IPFC) Working Party of Experts in Inland Fisheries held in Kathmandu, Nepal on 8-14 September 1988. As the tilapias (*Oreochromis* and *Tilapia* species) are becoming increasingly important for culture in over 30 developing countries including Malaysia, it is necessary to review and evaluate its current status as a basis for future fisheries planning and management -- especially in view of the poor understanding of the dynamics of the tilapia industry and the many unanswered questions on its impacts on the indigenous fish species and the aquatic environment.

An analysis of selected production and marketing systems based on data provided by private producers and marketing intermediaries, could help to understand the potential of the tilapia industry and to provide the directions for more efficient and streamlined research studies in this field. Such an analysis, although tentative due to the limited database, could at least provide a picture of the current investment climate and of the organizational structure of production and marketing. This information could be of use to government agencies such as the Ministry of Agriculture and the Federal Agricultural Marketing Authority (FAMA), which are currently undertaking, or planning to undertake, programs or activities involving tilapia. Some of these activities are the following:

(i) Extension and technology transfer of tilapia culture (Department of Fisheries, Malaysia);

(ii) Promotion of consumption of cooked tilapia (grilled, steamed, sweet-and-sour) (FAMA, Malaysia);

(iii) Promotion of consumption of more freshwater fish (FAMA, Malaysia); and

(iv) Information dissemination and technical advice on aquatic species (INFOFISH).

This paper attempts to respond to the following Terms of Reference:

(i) To provide statistical data on the present position of tilapia in catches from inland waterbodies, whenever possible;

(ii) To provide an account of culture-based tilapia fisheries (i.e., cages and regular stocking of waterbodies) and their significance in Malaysia;

(iii) To provide perspectives for the future expansion of tilapia fisheries, including constraints to tilapia production in Malaysia; and

(iv) To address any problems, wherever relevant, pertaining to poor marketability, competition with other species, fish diseases, stunting, and declining quality of broodstock.

Since tilapia production is carried out in various parts of Malaysia, it is not possible to undertake an in-depth analysis (particularly economic analysis) in every region of the country. This assessment therefore focuses on three major states where tilapia culture has been popular with the private sector (viz., Perak, Selangor, and Sabah) and on selected production systems elsewhere.

2. CURRENT STATUS OF THE TILAPIA FISHERIES

2.1 Major Species of Tilapia Introduced into Malaysia and Origins or Sources

Tilapia is an exotic fish in Malaysia, entering into the country by "introduction" and distributed within the country by "transfers". The major species of tilapia currently prevalent in Malaysia, their status of establishment in the aquatic environment, and their current commercial practice, are briefly described below.

2.1.1 Grey tilapia (*Oreochromis mossambicus* Peters 1852)

Oreochromis mossambicus Peters (Cichlidae) was introduced into Malaysia from Indonesia in 1943 and is self-reproducing in ponds. Until the 1970s, this species had not been commercially successful because it was not liked and was regarded as a low-quality product by consumers. It was also considered a nuisance fish by fish culturists because it bred profusely with high frequency and abundance such that fishponds became overcrowded quickly. Generally, fish farmers regarded grey tilapia as a pest and eradicated it when possible. In fact, this negative attitude still prevails in certain urban areas of the country. The hybrids may, however, eventually become an important food fish as the perception of grey tilapia has changed from that of a trash fish to that of an acceptable commodity.

Oreochromis mossambicus from Malaysia is reported to have been transferred to Thailand in 1949 and to Papua New Guinea (PNG) in 1954. In PNG, it has become widespread and is important in the capture fisheries (Pullin, 1985).

2.1.2 Nile tilapia (*Oreochromis niloticus* Linnaeus 1757)

It was not until the mid-1980s that the availability of the more attractive *Oreochromis niloticus* and its hybrids (e.g., red tilapia of Taiwan) has resulted in a complete turnaround in both producer and consumer attitudes regarding tilapia. Since that period, the Nile tilapia, *Oreochromis niloticus,* has gradually been recognized as a tool for increasing and sustaining fish yields (besides the cyprinids). This is because the species has many desirable features as a cultured fish species, like the following: (i) It is fast-growing; (ii) It is well-liked by consumers in comparison with the grey tilapia, being lighter in color; (iii) It occupies all trophic levels in reservoirs and lakes leading to good fisheries; (iv) It supplements poor stocks and supplants inferior species; and (v) Its use in culture-based reservoir fisheries and cage culture can be financially profitable.

Its availability for culture coupled with recent advances in monosex and cage culture have further stimulated the expansion of the tilapia industry in Malaysia, especially in recent years.

Much progress has been achieved in Malaysia as well as in other Asian countries (e.g., Thailand and Philippines) in the development of hatchery technology for the mass production of Nile tilapia fry for stocking into reservoirs and tin mining pools and for culture in cages and ponds. Both governmental and private hatcheries have concentrated on producing *O. niloticus* and red tilapia fingerlings (Table 1).

2.1.3 Red Tilapia

Red tilapia is a hybrid of *Oreochromis niloticus*. Most red tilapia are products of crosses of *O. niloticus* x *O. mossambicus*, with some involving *O. aureus* (Galman and Avtalion, 1983). The successful use of the Taiwan hybrids and of the hormone injection technology in sex reversal have resulted in the wider use of red tilapia in culture.

2.1.4 Blue tilapia (*Orerochromis aureus* Steindachner 1864 and *Tilapia rendalli* Boulenger 1896)

The country of origin and the importing country into Malaysia of these two tilapias cannot be established from the literature. These species are of marginal interest in Malaysia. *Tilapia rendalli* was reported to have been introduced into Sri Lanka in 1969 and has become important in the reservoir fisheries of that country.

Table 1
Tilapia fingerling production and their usage in Malaysia, 1988 and 1989

Hatchery	Fingerling Production (individuals)			
	Nile Tilapia		Red Tilapia	
	1988	1989	1988	1989
PENINSULAR MALAYSIA				
1. Government hatcheries in:				
Bukit Tinggi, Johore	920	3,000	559,603	462,899
Jitra, Kedah	359,459	227,262	171,642	444,371
Kong Kong, Johore	17,750	-	33,625	-
Enggor, Perak	-	15,950	-	50,200
PPIAT, Batu Berendam, Malacca	-	10,000	-	484,435
Sub-total	378,129	256,212	764,870	1,441,905
Numbers released into public water bodies	103,505		108,205	
Percentage of production	27.37		14.15	
Numbers sold to tilapia culturists	190,301		613,895	
Percentage of production	50.33		80.26	
2. Private hatcheries (26) in:				
Selangor	-		400,000	
Perak	30,000		40,000	
Sub-total	30,000		440,000	
Production (mt) from:				
Public water bodies	n.a.		n.a.	
Ponds and tin mining pools	2,350		241	
Freshwater cages	38.60		4.28	
SABAH				
Government hatcheries in:				
Babagon, Penampang	178,735			
Marakau, Ranau	103,902			
Keningau	75,610			
Kebayau, Kota Belud	59,820			
Gum-Gum, Sandakan	53,718			
Jimpangan, Beaufort	30,000			
Telupid	25,156			
Sub-total	526,941			
Monthly tilapia yield from freshwater ponds (mt)	15.82			
12,000 fry of Nile tilapia were sold/distributed to five private brackishwater fish culturists since June 1990 in Sabah				
SARAWAK				
Government hatcheries		116,424		29,434

2.2 Tilapia Yields and Management Inputs

2.2.1 Tilapia Capture Fisheries

The openwater fishery yields of tilapia vary widely among waterbodies. This variability is partly due to differences in size, location, and natural productivity of the waterbodies (reservoirs and river segments), the presence/absence of predatory fishes, and stocking efforts. On the whole, however, yields are determined primarily by the success of the stocking programs resulting in self-reproduction and subsequent natural breeding.

(i) Yields

Documentation on tilapia yields in Malaysian inland capture fisheries is poor, partly due to the higher preference given to cyprinids in increasing fish yield for food consumption purposes. Tilapia accounts for only 6.5 per cent of fish yields in comparison to the 60 per cent contributed by the cyprinids (Khoo, 1987).

(ii) Stocking

Very little has been done in the area of stocking of tilapia to support inland capture fisheries and the benefits from such efforts cannot be clearly ascertained. It is difficult to quantify the impacts of tilapia introduction on the Malaysian inland fisheries resources based solely on present observations on waterbodies stocked with tilapia. The lack of accurate data on quantities of fingerlings stocked vis-a-vis the volumes harvested, makes it extremely difficult, if not impossible, to do a quantitative evaluation of the actual contribution of tilapia stocking to fish production in inland waters. Furthermore, it is practically impossible to differentiate between the stocked fingerlings and those derived from self-reproduction of mature fish stocked earlier.

The wide variation in yields by species of tilapia and their contribution to the total fish production of inland waterbodies has constrained the wider use of tilapia for stocking in Malaysian openwaters. Other factors that have served to limit the optimum utilization of inland waters for tilapia production include the following: (i) difficulty in estimating the carrying capacity of a water body; (ii) poor data on fishing effort; and (iii) poor knowledge on the returns from stocking efforts. This notwithstanding, tilapia has been stocked in inland waters to enhance yields from the capture fisheries.

The grey tilapia, *Oreochromis mossambicus*, appears occasionally in the catches from the recreational and sewage oxidation ponds in urban areas, where it has been traditionally stocked as a sport fish and a biological filter, respectively. About 2,000 red tilapia fingerlings were stocked into the Sg. Samagagah, Krian River on 18 January 1990 but no information is available on its establishment in the system or on recaptures from that stocking. In 1988, about 378,129 fingerlings, or 27.37 per cent of the Nile tilapia, and 764,870 fingerlings, representing 14.15 per cent of the red tilapia, seed produced by the government hatcheries in Peninsular Malaysia were stocked in the open waters. Yields from these stocking efforts are not available, however. Free ranching-cum-cage

culture of Nile tilapia in six disused tin mining pools in Bidor has given an impressive yield of about 3.56 mt/ha/yr at a stocking rate of 10-11 fingerlings/sq m (or about two million fingerlings per crop).

2.2.2 Culture-based Tilapia Fisheries

More than 50 per cent of the total tilapia seed production (50.33 per cent for Nile tilapia and 80.26 per cent for red tilapia) in Peninsular Malaysia was distributed for culture. Correspondingly, the total harvests of *O. niloticus* and red tilapia from freshwater ponds and ex-tin mining pools were 2,350 mt and 241 mt, respectively, representing 30.2 and 3.1 per cent of the annual landings.

Production from tilapia cage culture was 38.6 mt for *O. niloticus* and 4.28 mt for red tilapia, equivalent to a contribution of 73.4 and 8.2 per cent, respectively, to overall cage culture production involving seven species.

In Sabah, a total of 526,941 tilapia fingerlings was produced in government hatcheries and distributed free to fish farmers in 1988 (Table 1). This figure represents a 35 per cent increase from the 390,174 fingerlings distributed in 1987 and an 85 per cent increase from the 290,980 fingerlings distributed in 1986, indicating the growing importance of *O. niloticus* as a culture species in East Malaysia.

Communications with commercial fish culturists, fish traders, and individuals involved in tilapia-related research production and management programs indicate that the tilapia industry in Malaysia is dynamic and offers considerable promise for expansion. The Nile tilapia and the red tilapia are the most favored species for commercial culture. Monoculture is most widely practised although two respondents contacted revealed plans to undertake mixed culture of exotic carps and catfish and a few operators practise integrated poultry-fish culture, with the chicken manure used to fertilize the ponds (Yap *et al.*, 1988 and 1989). Tilapia is reared either in ponds, disused tin mining pools, and cages.

(i) Freshwater Pond Culture

Tilapia is cultivated in freshwater and brackishwater ponds in the country. Freshwater pond culture is well developed, with production reaching nearly 8,000 mt in 1988, consisting mainly of tilapias and carps. In 1989, grey tilapia ranked first (2,070.37 mt) in terms of total fish production from freshwater ponds in the country, representing 28.19 per cent of the total of 7,343.68 mt (Malaysia Department of Fisheries, 1990). In contrast, the red tilapia production of 492.68 mt constituted only 6.71 per cent of total freshwater fishpond production. The major states that produce grey tilapia are Sabah (1,880 mt), Perak (98.03 mt), and Selangor (17.69 mt) while the major states that produce red tilapia are Selangor (181.28 mt), Perak (154.61 mt), Pahang Darul Makmur (57.62 mt), and Negeri Sembilan (48.31 mt).

In Sabah State in East Malaysia, there are 5,086 freshwater fishponds covering 461.91 ha with tilapia as one of the dominant cultured species. In 1988, the production of *O. niloticus* from seven districts was 15,820 kg representing 32.04 per cent of the total freshwater pond production of about 49,342 kg (Table 2); in four of the seven districts, Nile tilapia ranked first among the freshwater species grown in Sabah and in the other three districts, it ranked second to freshwater prawns (Table 2).

Table 2
Average monthly production (kg) of Nile tilapia in seven districts of Sabah in
(Department of Fisheries Sabah, 1989)

District	Freshwater ponds		Yields (kg)		Species	
	Number	Surface area (ha)	Nile tilapia	Total	Number identifiable	Dominant
1. Renau	721.00	75.43	3,878.00	6,091.00	6	tilapia
2. Tuaran	745.00	31.55	227.00	5,125.00	3	prawn
3. Kota Belud	1,231.00	178.44	2,738.00	10,040.00	5	prawn
4. Tambunan	960.00	55.09	4,321.00	12,781.00	6	tilapia
5. Keningau	963.00	66.20	2,438.99	4,360.68	7	tilapia
6. Tenom	315.00	25.45	1,848.00	4,425.00	6	tilapia
7. Beaufort	151.00	29.75	370.00	6,550.00	5	prawn
Average total monthly production (kg)			15,820.99	49,372.68		
Contribution (%)			32.04			

(ii) Brackishwater Pond Culture

The culture of Nile tilapia in brackishwater earthen ponds has been tried at the Sabah Fisheries Station using two culture approaches: one with male and female tilapia fingerlings, the other with all-male fingerlings (Cho, pers. comm.). In the first case, 330 fingerlings were stocked in a 0.03-ha brackishwater pond and cultured for six months. The pond was fertilized with 700 g urea and 79 g N-P-K and the fingerlings were fed with a total of 55 kg of chicken feed and 55 kg of rice bran over the rearing period. At the end of culture, 80 kg of fish, each weighing 243 g, on the average, were harvested.

In the second case using all-male tilapia, a total of 225 fingerlings was stocked in a 0.02-ha brackishwater pond fertilized with 500 g urea and 60 g N-P-K and fed with 136 kg chicken feed over a six-month period. The harvest yielded 115 kg of fish, each weighing 542 g, on the average, suggesting that monosex male culture of tilapia could give significantly better results as compared to the traditional approach. In the Philippines, Guerrero (1985) reported a harvest of 900 kg of tilapia, each weighing 100 g out of an initial stock of 10,000 fingerlings (with an average weight of two g) in a 1.2-ha brackishwater pond after five months of culture. The culture of tilapia necessitates proper acclimation of tilapia fingerlings to salinities between 15-30 ppt to

ensure good growth and survival. Brackishwater pond culture of tilapia has not yet gained popularity with the private sector except in East Malaysia. Since June 1990, about 12,000 tilapia fry were distributed to five private brackishwater fishfarms in Sabah but no feedback has been received so far.

(iii) Mixed Systems

The most popular production system in the country is the mixed system involving modifications of disused and undrainable/drainable tin mining pools supporting cage culture and land-based concrete tank culture system. The tilapia fingerlings are reared in mining pools and cages until they reach marketable size. The outdoor concrete tanks serve as conditioning/fattening tanks while the indoor concrete tanks serve as sorting/holding tanks for the marketable fish ready for sale. The mixed mining pool cage-tank system for tilapia produces about 14 mt/ha/yr. Variations in production level have been observed with different types of mixed farming systems. For example, small-scale nursery tanks/grow-out cages in Ulu Yam, Selangor produce about three mt/ha/yr while medium-scale nursery tanks/grow-out tanks and cages in Bidor, Perak produce 3.6 mt/ha/yr and large-scale breeding ponds/nursery and grow-out cages in Rawang, Selangor produce 7.6 mt/ha/yr. The key operational characteristics that influence the production levels are stocking rate, pool and pond size, rate and mode of water exchange, aeration facilities, labor force, and management attention.

(iv) Cage Culture

Commercial production of tilapia in double-netted netlon cages was first reported in Bidor in Perak and spread to nearby Rawang in 1987/88. Currently, there are about 400 floating cages in 38 ha of tin mining pools in the two major states of Perak and Selangor, and another 20 ha in Negeri Sembilan and Johore. As of January 1991, there were a few beneficiaries of government fish cage culture projects in Bidor (Tapah Farmers Association) and some 40 projects were in the pipeline.

The intensification of tilapia culture in floating cages in disused tin mining pools is foreseen to be the trend in the near future in view of the higher yields that can be achieved with minimal investment costs particularly with the use of netlon cages which have a longer life span. The netlon cages are made of PVC-material nets with mesh sizes of two to five cm or larger and lined internally with a finer net with a mesh size of one to two cm.

The stocking density used in floating cage culture varies from 6-20 fingerlings/ sq m. Nile tilapia fingerlings measuring about five cm are stocked and given artificial feeding. The fish grow to sizes of 300-350 g each in 3-3.5 months and further to 800-900 g in 5.5-6 months. The growth rate of the fish in cages is largely dependent on primary production in the surrounding waters, oxygen content and changes in water quality, and management approach (e.g., stocking density and spacing between cages). In Bidor, for example, cage culturists reported that oxygen depletion at night after a noon rainfall resulted in poor growth and mortality of tilapia in cages while the tilapia in the surrounding waters were unaffected.

2.3 Improvement of Tilapia Broodstock

Most cultured tilapia populations in Malaysia are assumed by culturists to be Nile tilapia and red tilapia from Taiwan. The choice of species is based mainly on commercial claims on heritability of the red color and on culture performance. Hitherto, the identity has been little studied and electrophoresis on new introduced tilapia populations has not been carried out regularly to verify these claims.

The commercial production of fingerlings of *O. niloticus* and red tilapia from Taiwan is done largely by the Department of Fisheries for sale to fish farmers and for free release in the open waters.

Poor growth of fingerlings due to inbreeding depression and/or depleted genetic variations (Huang and Liao, 1990) has been reported in tilapia commercial farms contacted in the present study. These problems and the great demand for tilapia seed have led to the adoption of practices meant to improve the broodstock and produce high-quality fingerlings including the following:

(i) Crossbreeding of different strains and hybridization: Some operators use the female or male breeders of another hatchery to crossbreed with their stocks in an attempt to avoid inbreeding.

(ii) Sex reversal by injection of the hormones 17-methyltestosterone and 17-ethyltestosterone: Growth of the sex-reversed tilapia is reported to be 25 per cent faster than the untreated fish and its unit price is double the latter.

In addition, the Malaysian Government could consider the use of promising strains in new breeding programs and the introduction of the best culture strains available, such as the Uganda strain and the Ghana strain, directly from Israel, Egypt, and Zaire. Pullin (1983) suggests that Israel, Africa (e.g., Lake Manzallah, Egypt), and Taiwan are the only reliable sources of *O. niloticus* and *O. aureus*.

2.4 Tilapia Economics: A Preliminary Account

The success, appropriateness, and expansion potentials of an industry are ultimately determined by its profitability. In practice, profitability is determined by variables like market conditions (national and regional), socio-economic conditions, environmental conditions at a given site, culture methods, technical and business management skills, and government policies. While a detailed analysis of Malaysian tilapia economics is beyond the scope of this review, it is possible to speculate on the potential impacts of increases in nationwide production on the economics of the industry.

Overall, the tilapia culture industry seems to be economically viable at present, the driving force being the present great demand for the fish which has resulted in supply shortages.

2.4.1 Fish Marketing

Two of the fishermen interviewed sold their catch to local fish merchants for transport to Singapore, while one sold the fish directly to local consumers from Kuala Lumpur, Pahang, and Johore. The main reasons given for selling to the fish merchants include convenience followed by controls on the alternative marketing channels by middlemen and the difficulty in getting road tax/permit for lorries with loads of more than four mt.

In Kuala Lumpur, Nile and red tilapia currently command retail market prices that are comparable to those of other prominent food fish such as exotic Chinese carps and catfishes.

The present demand-supply situation is not likely to last, however, and many analysts predict a drop in tilapia prices due to a glut in cultured tilapia in the world market. Even a 10 per cent reduction would be disastrous for extensive culture farms with production levels below three mt/ha. Intensive culture at production levels greater than three mt/ha can probably remain profitable even at price drops greater than 10 per cent. A 20 per cent decrease would virtually drive all tilapia culture operations into losses.

2.4.2 Costs and Returns

The levels of investment and earnings vary with the scale of operation and the type of culture used. For example, capital investment costs are highest in large-scale semi-intensive farms and relatively low for cage culture. Investment cost typically consists of capital costs and operational costs. Capital costs include construction cost (e.g., pond excavation, bunding, diking, water gates, rehabilitation of disused tin mining pools, and purchase of machinery and equipment (e.g., pumps, aerators, boats). Operational costs include fixed costs (e.g., salaries and wages, lease rentals, depreciation) and variable costs (e.g., fingerlings, feeds, fertilizers and other chemicals, repair and maintenance, fuel, part-time labor, harvesting costs).

A substantial net income (M$120,000) is realized by the medium-scale farm even though its production intensity is much lower than the large-scale farm. This is due to the low management cost and high production and value per hectare. On a monthly basis, the net cash income is equal to M$10,000, excluding the fish taken home for subsistence. This income is high, suggesting that tilapia farming is economically viable.

Tilapia production systems appear to be well-suited for adoption by small-scale producers because the initial capital investment, especially for cage culture, is not high, e.g., M$900-1,000/cage in urban areas and M$700/cage in rural areas using netlon PVC-made material. Large numbers of small-scale culturists have been attracted to cage culture and to small land-based hatcheries where the investment required is comparable to that of other multi-species culture systems.

3. FUTURE DIRECTIONS

3.1 Potentials

Malaysia has made significant advances in the use of tilapia to increase/enhance production in marginal waters through a combination of sustained support from Government and the extension of professional advice on the appropriate technology to fish culturists. That this has been achieved in derelict waterbodies is to the credit of all concerned and provides pointers for success elsewhere and in the future.

The future expansion of the tilapia industry in the country will depend largely on the ability of producers to respond to the lure of potential profits and on the response of the market to increases in production. The scope for intensification of tilapia production undoubtedly lies in culture-based fisheries, with the possible exception of capture fisheries in well-managed tin mining pools especially through cage culture which does not require high capital investment. As present cost and profit profiles indicate that cage culture is highly profitable, the situation being one of demand exceeding supply, much of the industry is heading towards this direction.

3.2 Constraints

There are a number of concerns regarding the rapid development of the tilapia industry and the use of exotic tilapias in fisheries management and aquaculture in Malaysia. These include the following: (i) possible effects of the exotics on the native species, especially if the exotic species become established in the wild; (ii) the lack of a sufficient labor force or a team of dedicated, well-trained fish culturists who can persevere through difficulties and risks; and (iii) production saturation and a market glut.

Increased tilapia production resulting from the new enthusiasm on the part of the producers will soon have impacts on marketing systems and on prices, and small producers may face difficulties in competing with large-scale operators. Possible constraints to further expansion of the industry may come in the form of distribution bottlenecks or a limited market absorptive capacity.

Other constraints are technology-related and are therefore easier to address. These include: (i) input supply limitations and high feed cost; (ii) deteriorating quality of broodstock and low availability of quality fry (at present, fry supply of seeds is heavily dependent on supply from Israel due to the shortage from Taiwan); and (iii) overcrowding of the available production space. In man-made lakes where cage culture has been shown to be suitable, fish cages have proliferated and the resulting overcrowding of the area has produced results detrimental to all the producers. In Bidor, Perak, small 50-acre tin mining pools have shown signs of overcrowding as marginal producers out for quick returns and short-term profits have proliferated in the area.

Other minor factors which can impact negatively on the tilapia industry are disease and energy/fuel cost. As the industry expands and more hatcheries are set up, the threat of disease becomes greater. Also, high energy and fuel costs may adversely affect the large-scale, remotely situated farms which generate their own electricity and are large consumers of diesel fuel. However, since energy costs are lower than 6.5 per cent of the operating costs of the large-scale semi-intensive farms (see Table 4), it is expected that these farms would not be significantly affected by fuel cost increases and shortages.

3.3 Mitigating Measures

The possible adverse impacts of drops in market prices of tilapia resulting from increased production may be offset by lowered production costs and more efficient use of the production system. For example, feed costs may be reduced if more efficient feeds are developed. Considering that feeds typically constitute the largest expense item in operating cost (at 47-63 per cent), it is essential that lower cost and more efficient feeds are developed to enable the further expansion of the tilapia industry. At present, imported tilapia feeds are costly, ranging in price from M$1.20-1.40/kg for large-sized tilapia, M$1.50/kg for medium-sized tilapia, and M$1.80/kg for fingerlings, as compared, for example, to chicken bran which sells at M$0.50-1.00/kg.

It is also possible to reduce the cost of fry from the present M$0.22-0.50/fry, the latter for sex-reversed fry, through improvements in broodstock maturation and spawning, improved fry feeds, and higher survival in the hatchery.

Finally, a more efficient use of the culture area could be promoted either through an increased number of crops per year from a given land area or through continuous stocking and harvesting of a given pool. This is presently done in a medium-scale farm which has extended the harvest period, increased production per hectare, and reduced production cost per kilogram.

3.4 Research Directions

3.4.1 Gaps in Knowledge

The present review has revealed the paucity of information available on Malaysian tilapia fisheries. Although some small-scale tilapia farms have been monitoring their own performances, it soon became obvious during the data-gathering process that the tilapia operators were not willing to disclose the required information, particularly those pertaining to profitability, in the name of confidentiality. Information is also not readily available on the impacts of tilapia on other fish stocks. The most that can be done is to approximate or speculate on these based on experiences from elsewhere (e.g., Petr, 1989; Welcomme, 1988; Pullin, 1985) and from insights gained from communications with fish culturists and government extension personnel.

It is feared that the major impact of tilapia transfers or translocations would probably be the destruction of ecotypic forms below the species level and negative effects on interspecies genetic pools due to hybridization, competition and predation, and pathogen and disease transfer.

(i) Hybridization

The adverse impact of introgressive hybridization is not yet obvious or has not been reported yet in most farms in Malaysia, except at a fish farm in Bidor, Perak State. In this 15-year old farm of diverse species (predominantly Nile tilapia), a decline in culture performance is apparent after several repeated production cycles. Although deteriorating water quality and declining productivity of the tin mining pools have been blamed for this, it has been suggested that interbreeding of previously-introduced *O. mossambicus* with Nile tilapia cultured stocks could have caused the observed decline in culture performance. *O. niloticus* populations in most Asian countries face the prospect of introgressive hybridization with *O. mossambicus*. This hybridization is suspected to lower the culture performance of the best species, as has already been experienced in the Philippines (Taniguchi *et al.*, 1985).

(ii) Competition: Impacts of Stocked Tilapia on Yields of Other Fish Species

Hitherto, the impact of tilapia stocking and management techniques on the natural resources of Malaysia has never been evaluated. Direct predation of tilapia on other fish species is unheard of. The impacts of predation of tilapia and the effects of low yield on inland fisheries have not yet been reported.

In the Bukit Merah Reservoir in Perak, the Fisheries Department introduced a variety of exotic species and artificially-hatched fingerlings of indigenous species in the late 1960s with a view to increasing fish production. While the Fisheries Department (Parit Buntar, Perak, 1978 as cited in Yap, 1982) listed *O. mossambicus* among the fish species in the Bukit Merah Reservoir, Fernando and Furtado (1975) reported its absence. In a comprehensive faunistic-ecological survey (Yap, 1982-1990), *O. mossambicus* was not seen or caught during the survey. Though high predation cannot be ruled out (Yap, 1982), the disappearance of this species cannot be readily explained unless the original records were erroneous.

In large reservoirs of Southern India (Sreenivasan, 1988), tilapia does not affect the carp fishery. Large predators like *Wallago attu* Schneider and small predators like *Notopterus notopterus* Pallas reduced the dominance of tilapia without interfering with the major carp stocks. In smaller reservoirs, tilapia has been giving fairly high yields but the stocked carps failed to appear in the catches.

(iii) **Pathogen/Disease Transfer**

Although tilapia disease problems have not been reported to significantly slow the growth of tilapia production, it is becoming a problem especially in hatchery production and in high-density culture. Since the future expansion of tilapia production will necessarily mean the establishment of more hatcheries and possibly more intensive farms, it is important that greater efforts are exerted in the area of tilapia pathogen/disease transfer.

3.4.2 Research Needs

To complete the documentation on the use of tilapia in Malaysian fisheries management, it is necessary to conduct an in-depth analysis of selected production and marketing systems based on data provided by private input suppliers, producers, and marketing intermediaries. The findings from such analysis should form the basis for decisions or judgment concerning the suitability of the introduced tilapia to support and enhance the desired fishery.

The two main areas which could benefit from research leading to the further expansion of tilapia fisheries in Malaysia are the following: (i) biological impact assessment; and (ii) production monitoring and economic analysis to determine baseline levels and identify problem areas.

Specific areas for research and development work could include the following:

(i) Biological effects of tilapia on indigenous species;

(ii) Tilapia breeding, particularly the introgression of genes into interspecies tilapia, and the mechanisms involved in introgression, genetic fatigue, and inferior stocks;

(iii) Tilapia feeds and nutrition to improve culture performance and lower cost of production;

(iv) Disease and quarantine to guard against the risk of spreading diseases, including the practicability of adopting the EIFAC Code of Practice on Introduced Inland Aquatic Organisms; and

(v) Development of a universally and/or nationally accepted protocol to evaluate exotic aquatic organisms before they are introduced into the country.

4. CONCLUSION

An extensive database is required for the development of production-predictive models that could be used as a tool for the expansion of the tilapia fisheries in Malaysia. It is necessary that such models be developed on the basis of both technical and socio-economic considerations, including cost-benefit analyses of alternative stocking

practices/management approaches inasmuch as the utilization of tilapia species for yield enhancement is often determined by social and economic factors including consumer acceptance, market demand, and profitability. The findings and conclusions arrived at using these models, would assist fishery planners and managers in their objective assessment of the prospects/potentials of tilapia fisheries expansion in Malaysia, especially if they also spell out the difficulties which large-scale introductions may bring about.

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REVIEW OF TILAPIA IN PAPUA NEW GUINEA

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1. INTRODUCTION

Tilapia, *Oreochromis mossambicus*, was brought to Papua New Guinea (PNG) in the late 1950s by the then Australian Administration of the Territory of Papua New Guinea. The original purpose of importation was for aquaculture in response to a perceived scarcity of native freshwater fishes.

Almost immediately after its importation, *O. mossambicus* escaped from ponds into natural waterbodies. Since there was little control of the internal transfer of this species, it now occurs in natural habitats in several regions of PNG, and in two of them, it forms the basis of capture fisheries.

In contrast, the aquaculture performance of *O. mossambicus* has been very poor and its contribution to total fish production has been insignificant due to factors like poor management techniques and lack of expertise (aquaculture was initially unknown to the PNG resident population), ineffective extension work, and problems of stunting of the fish. By the late 1960s, in response to the failure of *O. mossambicus*, aquaculture activities shifted to common carp, *Cyprinus carpio*.

2. TILAPIA IN CAPTURE FISHERIES

The most important area where *O. mossambicus* has become important in capture fisheries is in the Sepik/Ramu River basin in the north of the country. In 1964, *O. mossambicus* escaped from ponds within the Sepik/Ramu catchment. By the early 1970s, the fish was considered so abundant that plans were made to develop a major commercial inland fishery based solely on this species to produce salted and sun-dried tilapia fillets. Initial estimates of production were over-optimistic and based on direct comparisons with yields achieved in rivers in Africa. Because of inaccurate yield estimates and other economic factors, the Project was not economically successful. Despite the limited success of the Sepik Salted Tilapia Project, it produced a good quality produce that became popular among the local people, especially in the highland areas where natural fish stocks were very poor. Moreover, *O. mossambicus* remains the only freshwater fish species in the country ever to be subjected to commercial fisheries development trials.

Although attempts were made to develop the commercial tilapia fishery, limited attention was given to the importance of tilapia in the subsistence and artisanal fishery in the Sepik/Ramu. The first estimates of fish yield for the Sepik River based on actual data from the river itself showed that yield from floodplain regions of the river were in the region of 4,000-5,000 mt/yr (Coates, 1985). More importantly, *O. mossambicus* accounts for about half of the artisanal/subsistence catch and about 65 per cent of the weight of fish landed in local inland markets in the Region. The remainder of the catches and landings are based upon a number of native fish species, none alone rivalling tilapia in importance. Additional data obtained more recently for the adjoining Ramu River system indicate that catches of *O. mossambicus* from the Sepik/Ramu basin as a whole are in the region of 3,000 mt/yr, making it, by far, the most important single fish species in PNG fisheries, including marine species (except tuna where large catches are taken out by foreign fishing fleets and never landed in PNG).

The Sepik/Ramu tilapia fishery is by far the largest in PNG due to the size of both the resource and the fishing population. *O. mossambicus* also contributes significantly to catches in some other regions but limited or no fisheries data exist for those areas. There is a significant *O. mossambicus* fishery in the outskirts of the capital city, Port Moresby, in a small but productive wetland (Waigani swamp). Although production of tilapia from this wetland has not been quantified, it could easily rival that from the local marine/coastal fishery.

Common carp, *C. carpio*, like *O. mossambicus*, has also escaped from fish ponds in PNG and produced feral stocks. The more recent entry of common carp into the Sepik/Ramu has been monitored by Ulaiwi (1990) who considers the species to be already contributing significantly to the fishery. However, since common carp is still spreading within the Basin and stocks have yet to stabilize, it is too early to compare the performance of common carp with *O. mossambicus* in the capture fishery in any detail.

3. BIOLOGY AND ENVIRONMENTAL EFFECTS OF *O. MOSSAMBICUS*

The biology of *O. mossambicus* in the Sepik/Ramu has been reviewed by Redding (1989). The species differs little from its known general habits which have been documented extensively in other regions. *O. mossambicus* is essentially a quiet water, floodplain swamp, and lake dweller. In these habitats, such as those in floodplain regions of the Sepik/Ramu, the species grows to a large size (up to 1 kg but generally 0.4-0.5 kg) and is highly productive compared with the native species. *O. mossambicus* also inhabits tributary rivers and streams in foothill regions. However, in such environments, it stunts and is far less productive. Nevertheless, where it occurs, it contributes significantly to fish biomass and is often the most important species, especially in streams adjacent to lowlands (Van Zwieten, 1990a).

As very limited information on fish ecology in the Sepik/Ramu was available prior to the introduction of *O. mossambicus*, the effects of *O. mossambicus* on the native fish stocks could only be speculative. However, two factors are particularly relevant. First, based on extensive studies of the biology of all of the native fish species (Coates, in

press) and that of *O. mossambicus* (Redding, 1989), it is concluded that no major competition is likely to have occurred. In contrast to the vast majority of native species, *O. mossambicus* preferentially inhabits floodplains. In addition, its detritivorous habit is totally different from the feeding habits of all of the native species. The species is considered to have been successful in the Sepik/Ramu because of its ability to exploit previously underutilized environments and resources. Second, an extensive survey of the fish fauna of the entire Sepik/Ramu basin from 1980 to 1987 (Allen and Coates, 1990) still recorded all species known to be present prior to the introduction of *O. mossambicus*. Although shifts in the ecological balance of the river system cannot be discounted, there is certainly no evidence of *O. mossambicus* causing extinctions of native species despite its dominance of the fishery of the basin for over 25 years.

During previous outbreaks of ulcerative fish disease in the Sepik/Ramu, it was noted that *O. mossambicus* appeared to be less susceptible than many of the native fish species (Coates *et al.*, 1989). The dominance of *O. mossambicus* in catches in most areas may have lessened the potential impact of epizootics on the local fish stocks. In areas where no *O. mossambicus* occurred, stocks of native species were obliterated by disease, causing serious impacts on the local fishing communities (Coates *et al.*, 1989). *O. mossambicus* also appears relatively free of parasites when compared with the often heavy, natural host-specific, infestations present in many of the native fish species in the Sepik/Ramu (Womersley, 1990).

4. MANAGEMENT AND DEVELOPMENT OF THE TILAPIA FISHERY

There is presently no direct management of the *O. mossambicus* fishery and all aquaculture activities using this species have either ceased or are discouraged. The management of the Sepik/Ramu fishery involves its long-term development via the stocking of further species. The existing fishery within the Sepik/Ramu is considered resource-limited due to the low species diversity and production of the native fish fauna (Coates, 1987) resulting in both reduced yields (Coates, 1985) and ichthyomasses (Van Zwieten, 1990b).

For three years, the FAO Sepik River Fish Stock Enhancement Project evaluated the feasibility of stocking the river basin. Throughout the evaluative process, the Project adhered closely to the Code of Practice (Turner, 1988) and in 1990, recommended that the Basin be stocked with suitable species approved under Code procedures. That recommendation was endorsed unanimously by the independent Advisory Group established in line with the Code (Coates, 1990a). Considerable attention was then given to species suitable for stocking.

Tilapia rendalli was recommended for introduction as a macrophyte feeder and received the highest support from the Advisory Group among two other species, both gouramis already present within PNG but not the Sepik/Ramu (Coates, 1990b). The advantages of *T. rendalli* as opposed to alternative macrophyte feeders, are: (i) the comparatively large information base on the species' habits and effects in other regions; (ii) its ease of handling and breeding; (iii) the ability to obtain stocks of known genetic

origin; (iv) the ability to obtain stocks quarantined at source; and (v) the indication that there would be no consumer objections to *T. rendalli* in view of the popularity of *O. mossambicus* in the Region. *T. rendalli* stocks have already been imported into the Sepik/Ramu (from the Institute of Aquaculture, Stirling, Scotland) and stocking of PNG-raised fingerlings into the Basin has already commenced.

The stocking of *T. rendalli* is the only directly tilapia-related fisheries management activity that is presently ongoing in PNG. While *T. rendalli* is not presently used in aquaculture in PNG, its potential advantages make it attractive for introduction. In all evaluations regarding further species introductions, the status of existing *O. mossambicus* stocks is a major consideration in view of its importance to the fisheries. Therefore, future management of the Sepik/Ramu fishery via further stocking considers management of the *O. mossambicus* stocks and pays particular attention to their conservation. For example, the introduction of other maternal mouthbrooding tilapia species (i.e., *Oreochromis sp.*) was recommended as inadvisable because of the unknown consequences of hybridization with the existing *O. mossambicus*.

5. SUMMARY

The introduction of *O. mossambicus* is considered to have been a fortuitous accident in PNG, especially for the Sepik/Ramu river system. The species never fulfilled its original intended role in aquaculture but feral stocks now comprise the most important inland fishery resource in the country. The species is popular among the local population and accounts for over half of the fisheries production from lowlands in the Sepik/Ramu. It is the only freshwater fish species ever to form the basis of an inland commercial fishery and its environmental effects have caused little controversy in PNG. Management of the tilapia fishery involves the stocking of a second species, *Tilapia rendalli*, after extensive pre-introduction evaluations following recommended codes of practice.

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TILAPIA AND THE MANAGEMENT OF INLAND WATERS: THE PHILIPPINE EXPERIENCE

by

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1. INTRODUCTION

The inland waters of the Philippines have been managed through the introduction and stocking of various fish species, a practice started in the 1950s, and through the application of aquaculture systems and practices, mainly in pens and cages, starting in the early 1970s (Baluyut, 1983). Among several fish species used for stocking and culture, tilapia has become very important and in some instances, replacing milkfish as the most dominant species in freshwater lakes.

The Mozambique tilapia (*Oreochromis mossambicus*) was first brought into the Philippines from Thailand in the 1950s to augment milkfish production (Guerrero, 1986). Its intended use as a species for culture in ponds did not gain popularity, however, due to problems encountered in its rearing, primarily on account of its highly prolific nature giving rise to overcrowding and stunting (Fermin, 1988).

In the '70s, with the new interest in freshwater aquaculture, the Nile tilapia (*Oreochromis niloticus*) was introduced from various sources. Increased acceptance by producers and consumers of this faster growing and more attractive species and the improvement of management technologies, have spurred the rapid growth of the tilapia industry starting in 1972. At present, the Philippine tilapia industry can be characterized as dynamic and with great potentials for expansion despite the presence of certain constraints.

This paper discusses the role of tilapia in the management of inland waterbodies in the Philippines, reviews the status of the local cage culture industry, particularly in Laguna de Bay, and presents a case for the continued utilization of tilapia in the freshwater fisheries development of the country.

2. OVERVIEW OF THE TILAPIA FISHERIES IN THE PHILIPPINES

The tilapias rank with milkfish as the most extensively used finfish in the country's inland waters (PCARRD, 1985). They are stocked in lakes and reservoirs and farmed in land-based systems (i.e., fishponds) as well as in water-based enclosures (i.e.,

fishcages and fishpens). Tilapia culture has spread all over the country and is carried out on a small, medium, and large scale. The major tilapia-producing areas are found in Central and Southern Luzon, the Bicol region, and Southern Mindanao.

2.1 Species Used

O. niloticus is the most preferred species for stocking and culture for a variety of reasons. It is fast-growing, reaching 80-100 g in four months in fertilized ponds or 200 g in five to six months in cages with supplemental feeding. It is sturdy and disease-resistant, tolerates low dissolved oxygen concentrations of one ppm, is able to subsist on a diverse diet, and withstands crowding. More importantly, it has a good consumer acceptability because of its size and color.

Other species available locally include *O. mossambicus, O. aureus*, and *T. zillii* (Table 1). Red tilapia, believed to be a mutant of *O. niloticus* and the hybrid male *O. aureus* x female *O. niloticus*, has also been brought into the country from Taiwan. Red tilapia has been the subject of hybridization trials by the private sector which sees in the fish its potential for large-scale commercial culture and export to international markets. A recent article tells of the successful development of a "golden hybrid tilapia" by a private firm, Bio Research, after 20 years of continuing research and development work (Pantangco, 1990).

Table 1
Tilapia introductions in the Philippines, 1950-1982 (PCARRD, 1985)

Species		Date Acquired	Source	Recipient Agency
O. mossambicus		1950	Thailand	BFAR
O. niloticus	(Uganda)	1972	Israel	LLDA
	(Egypt)	1977	Thailand	BFAR
	(Ghana)	1977	Israel	CLSU
	(Ghana)	1977	Singapore	BFAR
	(Ghana)	1978	Singapore	SEAFDEC
		1979	Israel	CLSU
		1979	Japan	CLSU
		1979	Singapore	CLSU
	(Ghana)	1982	Israel	Private Sector
O. aureus		1977	USA	CLSU
	(Israel)	1977	Singapore	BFAR
	(Israel)	1978	Singapore	SEAFDEC
		1979	Singapore	CLSU
		1979	Israel	CLSU
		1980	Taiwan	CLSU
	(Israel)	1982	Israel	Private Sector
T. zillii		1978	Taiwan	
Red tilapia (hybrid)		1979	Taiwan	SEAFDEC
Red tilapia		1981	Taiwan	Private Sector
		1982	Taiwan	Private Sector
O. hornorum x O. mossambicus		1971	Singapore	Private Sector

2.2 Production and Yields

In 1989, a total of 101,642 mt of tilapia was produced in the Philippines, of which 19,972 mt were caught from the wild and 81,630 mt were harvested from aquaculture operations (DA/BFAR, 1990). This total output is about double the estimated production of 50,200 mt in 1985 (Guerrero, 1986).

As shown in Table 2, tilapia production from freshwater capture fisheries accounted for about nine per cent of the country's total production from fish capture. This production volume of about 20,000 mt is higher than the 17,824 mt recorded in 1987 but lower than the 31,407 mt in 1984 (Table 3). It is interesting to note, however, that while production has fluctuated from a high of 31,407 mt in 1983 to a low of 17,824 mt in 1987 (or a range of 13,583 mt), the percentage contribution of tilapia to total inland municipal fishery production has remained relatively stable at around seven to nine per cent (Table 3). This is apparently due to the fact that over the years, catches of the other species, mostly endemic or indigenous (e.g., snakehead, mudfish, freshwater catfish) have declined in Philippine lakes (Tables 3 and 4).

Table 2
Production from inland water capture fisheries, 1989
(DA/BFAR, 1990)

Species	Volume (t)	% to Total
Snails	124,231	55.89
Tilapia	19,972	8.99
Carps	11,329	5.10
Tawilis *(Harengula tawilis)*	10,650	4.79
Freshwater clams	9,912	4.46
Freshwater shrimps (Palaemonidae)	8,104	3.65
Freshwater goby	7,428	3.34
Others (mostly endemic)	30,631	13.78
TOTAL	222,257	100.00

Table 3
Inland municipal fishery production by major groupings, 1983-1987 (BFAR Statistics, 1987)

Grouping	1983		1984		1985		1986		1987	
	Volume (t)	% to Total	Volume (t)	% to Total	Volume (t)	% to Total	Volume (t)	% to Total	Volume (t)	% to Total
Molluscs	209,101	55.8	193,449	64.6	165,170	63.5	149,980	56.5	164,769	67.4
Crustaceans	9,329	2.5	12,937	4.3	15,977	6.1	19,298	7.3	11,078	4.5
Fish										
Milkfish	6,100	1.6	3,060	1.0	1,694	0.7	4,701	1.8	1,018	0.4
Tilapia	31,407	8.4	22,295	7.5	18,056	6.9	23,681	8.9	17,824	7.3
Carps	32,020	8.5	10,091	3.4	10,945	4.2	15,717	5.9	11,031	4.5
Others (19 species)	86,897	23.2	57,410	19.2	48,408	18.6	51,873	19.6	38,911	15.9
TOTAL	374,854	100.0	299,242	100.0	260,250	100.0	265,250	100.0	244,631	100.0

Table 4
Inland municipal fishery production (t) by species, 1983-1987 (BFAR Statistics, 1987)

SPECIES	1983	1984	1985	1986	1987
PHILIPPINES	374,853	299,242	260,250	265,086	244,631
FISH					
Bangus (Milkfish)	6,100	3,060	1,694	4,701	1,018
Tilapia (Cichlid)	31,407	22,295	18,056	23,681	17,824
Maliputo (Carangid fish)	1,309	518	33	37	144
Carp	32,020	10,091	10,945	15,717	11,031
Ayungin (Freshwater grunt)	2,213	6,968	5,188	4,044	2,933
Biya (Freshwater goby)	19,405	9,370	7,809	7,308	6,129
Kanduli (Freshwater catfish)	14,900	4,238	2,635	3,424	2,377
Dalag (Mudfish, snakehead, murrell)	25,976	11,420	12,010	10,508	7,521
Hito (Freshwater catfish)	1,941	4,416	5,740	7,681	5,220
Gourami	4,719	2,944	2,364	2,323	1,770
Tawilis (Freshwater sardines)	4,409	8,474	6,179	7,220	9,939
Martiniko (Climbing perch)	9,801	5,154	3,511	4,472	1,551
Eel (Freshwater eel)	228	656	299	331	483
Dulong (Starry goby)	829	279	207	2,080	21
Sinarapan (Mistichtys luzonensis)	50	51	80	65	70
Buan-buan (Tarpon)	6	-	22	50	14
Kapak (Mullet)	438	720	511	503	541
Kitang (Spadefish)	-	-	3	9	68
Black bard	672	2,202	-	-	-
Gono (Silverside)	-	-	1,817	1,635	72
Bidbid (Ten pounder)	-	-	-	19	43
Alakaak (Croaker)	-	-	-	-	15
CRUSTACEA	9,329	12,937	15,977	19,298	11,078
Talangka (Freshwater crabs)	165	321	266	244	322
Ulang (Freshwater lobsters)	84	104	7	3	7
Alimango (Mudcrabs)	135	374	244	301	224
Hipon (Freshwater shrimps)	8,945	12,138	15,460	18,750	10,525
MOLLUSCS	209,101	193,449	165,170	149,980	164,769
Tulya (Freshwater clams)	46,710	43,078	33,432	36,993	10,907
Cabibi (Freshwater clams)	5,209	3,563	5,227	3,372	2,529
Kuhol (Freshwater snails)	15,053	11,315	8,362	5,638	4,792
Suso (Freshwater snails)	142,129	135,493	118,149	103,977	146,541

In terms of its contribution to total aquaculture production, tilapia is second to milkfish, with a 12.98 per cent share of total production or about half of that contributed by milkfish (Table 5). Most of this production comes from the fishpens and fish cages in Region IV where Laguna de Bay is situated. No accurate statistical data are available, however, to support this generally known and accepted observation.

Table 5. Production from aquaculture, Philippines, 1989 (DA/BFAR, 1990)

Species	Volume (t)	% to Total
Seaweeds	268,701	42.69
Milkfish	192,896	30.65
Tilapia	81,670	12.98
Shrimps/Prawns		
Tiger prawns	43,539	
White shrimps	3,461	7.61
Endeavor prawns	866	
Mussels	16,403	2.61
Others	21,809	3.46
TOTAL	629,345	100.00

Note: Aquaculture production includes production from freshwater and brackishwater fishponds, fishpens and fish cages, and mariculture sites for oysters, mussels, and seaweeds. Production from aquaculture in reservoirs is not included.

There is also no published information on production from tilapia cages in the major reservoirs where floating cages have been set up by residents in the adjacent areas, although it is known that cage farming of tilapia is practised in 18 lakes and reservoirs in the country (PCARRD, 1985). It is certain, however, that in some reservoirs, particularly Magat Reservoir in northern Luzon, tilapia has been successfully grown in cages and a flourishing cage culture industry may well be on the way to being established as an important source of livelihood for the local communities (Digal, pers. comm.).

2.3 The Tilapia Cage Culture Industry

The culture of tilapia in cages in the Philippines was initiated in 1967 on the shores of lakes Sampaloc, Calibato, Palakpakin, and Bunot in San Pablo, Laguna (Baluyut, 1983). It was first tried in Laguna de Bay in 1974, commercially tested in 1977, and expanded rapidly starting in 1980-1981 along the Binangonan-Cardona side of Talim Island. Following its commercial success in Laguna de Bay and the seven lakes in San Pablo, Laguna, tilapia cage farming was introduced in the other freshwater lakes - first in Luzon (e.g., Buhi, Bato, Naujan, Taal) and then in Mindanao (e.g., Mainit,

Buluan, Lanao) - and in reservoirs (e.g., Pantabangan, Magat, Angat) in the country. Yields vary depending on factors including the natural productivity of the waterbody, water temperature, stocking densities, and management, among others.

2.3.1 Design and Construction

The cages are generally made of bamboo (and sometimes of wooden frames) with nylon netting sewn similarly to an inverted mosquito net. They are either fixed or floating, depending on the depth of water at the site. Floating cages are usually found in deep lakes and reservoirs like those in San Pablo, Laguna with depths exceeding five m, and fixed cages are used in shallow waters like Laguna de Bay whose average depth is only 2.6 m. Fixed cages rest on the lake bottom and usually occupy the full water column; they are kept intact in a hanging position by rigid poles staked around its perimeter and by floats on its top surface (Fig. 1). They are held in place by bamboo poles staked firmly 30 cm below the bottom substrate. The net flooring may or may not touch the substratum while the upper rim is kept at least 0.5 m above the water level. The cages may or may not be covered. Some fish cage operators prefer to construct covered cages in spite of the higher cost if only to provide better protection to their fish stocks. (During the typhoon season, they submerge the cages under water to prevent or minimize damage from floating debris or prevent fish losses from overtopping of the cages during times of high lake level.) The cages are usually arranged in clusters or modules of 2-20 units per module and provided with a perimeter fence made of bamboo poles set about one m apart (Fig. 2). The cages can also be set up beside fishpen enclosures, as in Laguna de Bay.

Floating cages are suspended in water by flotation devices like styrofoam, steel or plastic drums, PVC pipes, and bamboo poles around the net enclosure (Baluyut, 1989). They are anchored to the bottom of the lake by a metal weight at the end of anchor lines tied to the corners of the cage framework (Fig. 3). A freeboard of one m is left above the waterline.

Fixed cages are simpler to construct than floating cages and are cheaper by about 40-50 per cent. The higher cost of floating cages is due to the need to provide them with buoyant collars or flotation and anchorage devices which together account for more than 50 per cent of the total capital outlay for the floating cage (Lopez, 1990). In the Philippines, the required investment (capital and operating expenses) for fish cages has gone up by 45-60 per cent in the last five years as a result of the abrupt increases in the costs of construction materials and production inputs. At present, a total investment of about P20,000 would be required to fabricate and operate a floating cage measuring 10 x 20 x 5 m; a fixed cage measuring 10 x 20 x 3 m would require an investment of about P10,000 (Lopez, pers. comm.).

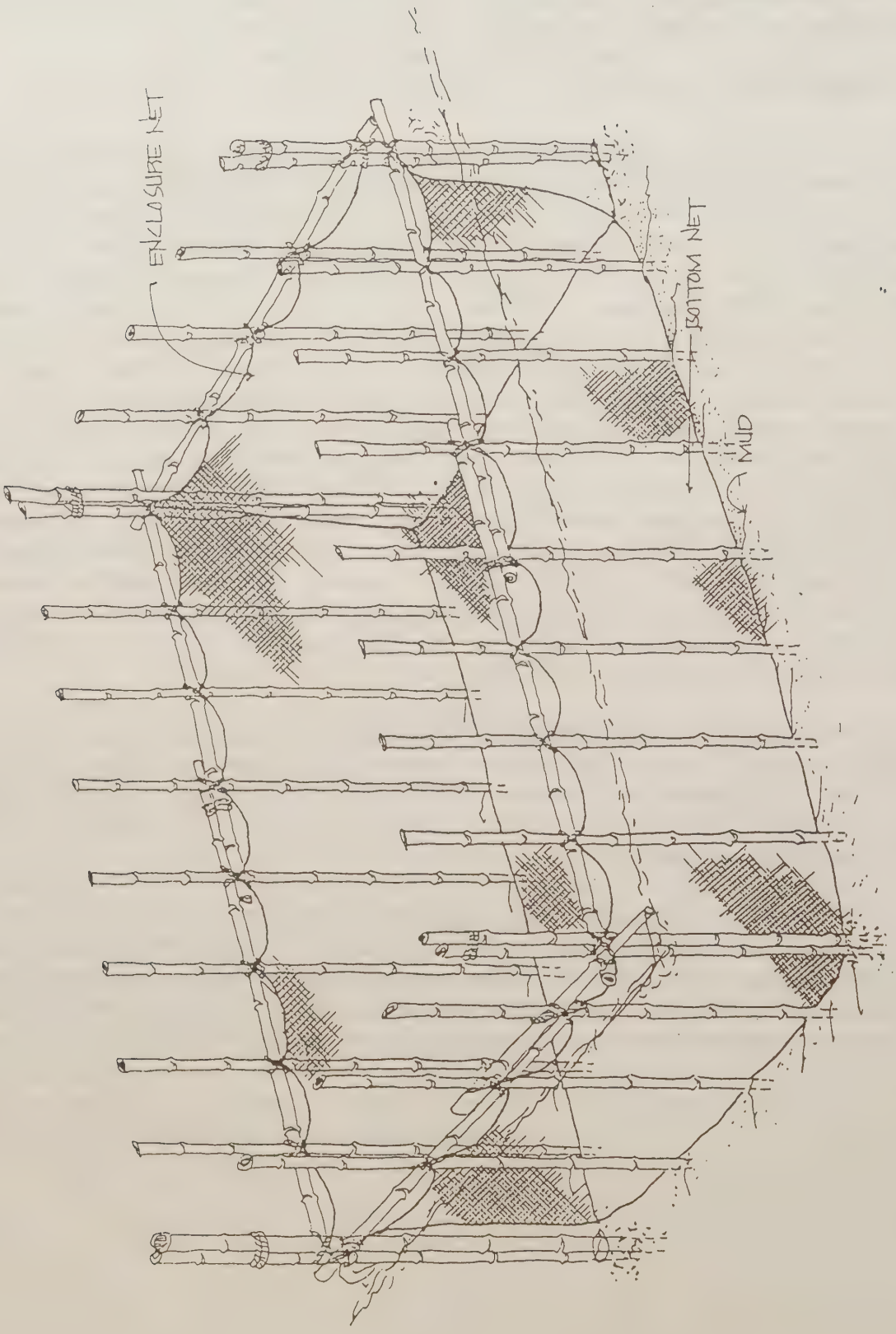

Fig. 1. Schematic diagram of a typical fixed cage in Laguna de Bay (from Lopez, 1990).

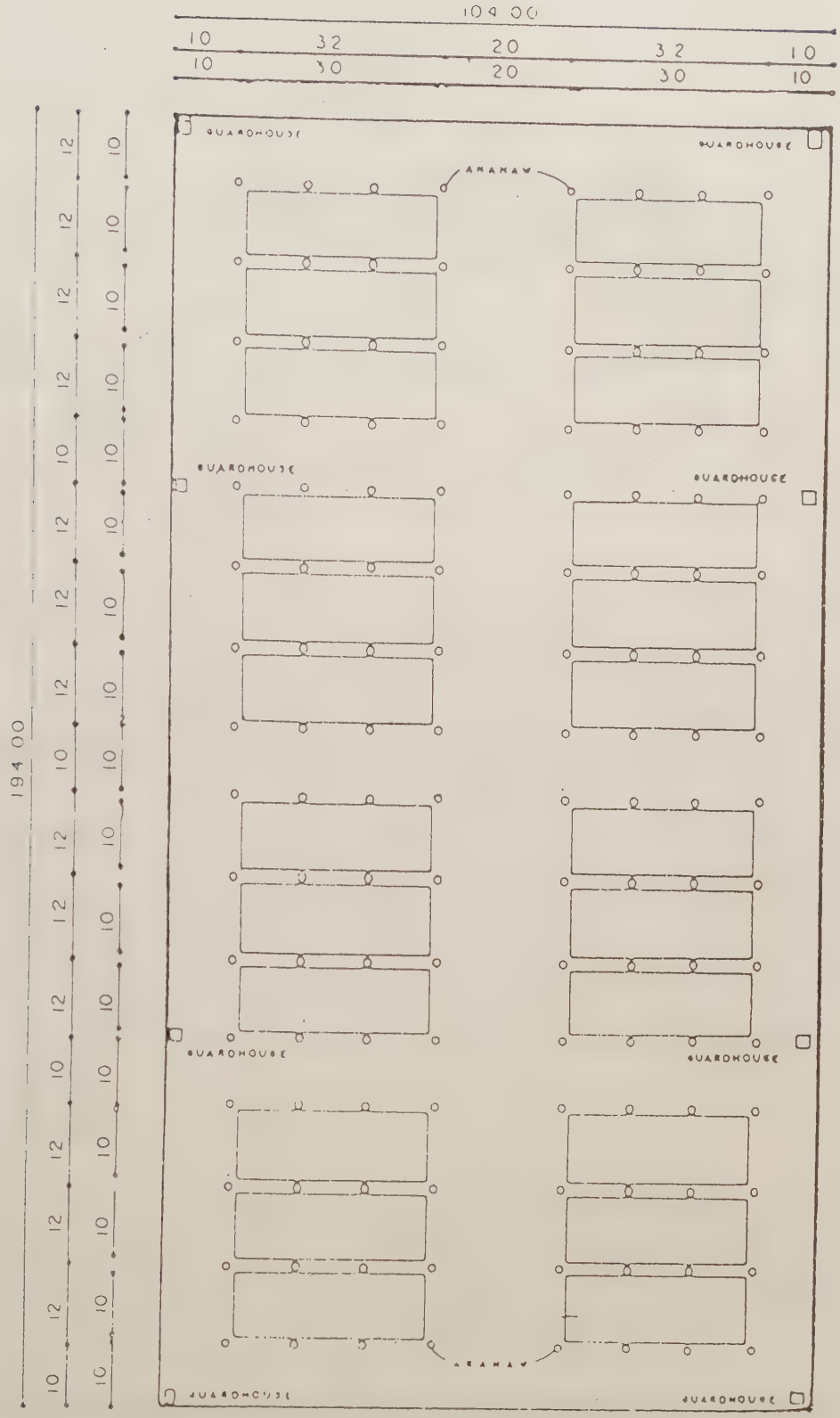

Fig. 2. Eight 3-cage modules enclosed by a common perimeter fence (from Baluyut and Alferez, 1988).

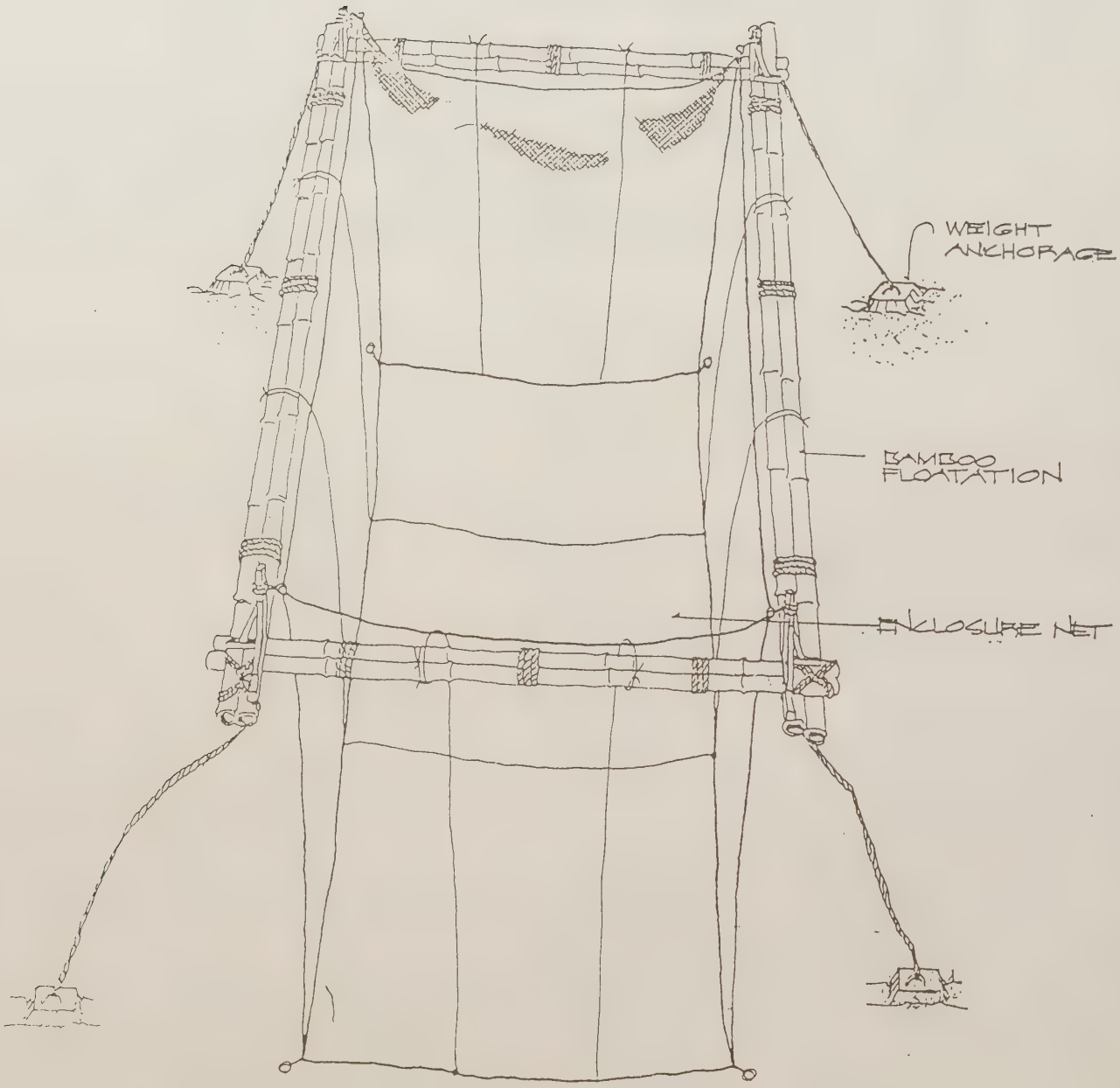

Fig. 3. Diagram of a typical floating cage in Sampaloc Lake, San Pablo, Laguna (from Lopez, 1990).

2.3.2 Operation and Management

Tilapia cages are stocked at varying densities depending on water productivity. In Laguna de Bay, the stocking rates used during the early years of the industry ranged from 30-40 individuals/sq m without supplemental feeding; this has gone down to 4-10 individuals/sq m even with supplemental feeding in view of the greatly diminished natural fertility of the water. In the other lakes, the stocking densities used are: 50/cu m in Lake Bato, which has a high productivity; 12/sq m in Lake Sebu; 14-18/sq m in San Pablo; and 10/cu m in Lake Buhi (PCARRD, 1985).

Fingerlings weighing 10-15 g are preferred for stocking. These are usually produced by the grow-out operators themselves or purchased from outside. (A brief discussion on hatchery operations is presented in Section 2.3.3 below.)

The tilapia are reared for at least four months. To promote growth of the fish, feeding is necessary in some lakes (e.g., San Pablo lakes) or in the same lake during times of low water productivity. Some fishfarmers use cheap, low-protein feeds (e.g., rice bran and ipil-ipil leaf meal) to supplement the natural food available in the water. Farmers with better financial means resort to commercial fish feed preparations which cost from P20-P35/kg depending on their crude protein content. These are given at varying proportions mainly as a function of stocking densities.

Marketable fish weighing at least 80-100 g apiece are harvested by scooping out of one corner of the cage. Market prices vary with the size of fish harvested and the season of harvest. Present selling prices for tilapia in the Laguna area range from P35-P45/kg for fish weighing around 200 g, which are grown over a rearing period of five to six months. Prices are usually better during the holiday season (around December) and during Lent. (The Filipinos, being predominantly Catholic, consume a lot of fish during the lenten season when they are supposed to refrain from meat on Fridays.)

2.3.3 Fry and Fingerling Production

The production of tilapia fry is carried out either in land- or water-based systems. Fish used for breeding are 50-80 g in weight or three to four months old. They are usually given feeds with 20-30 per cent crude protein at three per cent of body weight. Males and females are kept in separate cages where they are fed and conditioned before breeding. They are replaced regularly, usually after one year.

The hapa method is the easiest and simplest way of breeding tilapia (PCARRD, 1985). The net enclosures vary in size depending on the scale of operations. In Laguna de Bay, the hapa cages measure 3 x 2 x 2 m or bigger and are usually stocked with 48 breeders per hapa at a sex ratio of one male to three females. Double net hapas consisting of an inner coarse-meshed net cage enclosed by an outer fine-meshed cage facilitate fry collection and breeder replacement and are more efficient than the

traditional fry hatchery system. At the LLDA's ADB-funded Hatchery-Nursery Complex where this method was employed, fry production exceeded target levels by as much as 50 per cent (Baluyut and Alferez, 1988).

In using this method, the fry produced by the breeders in the inner net pass through the mesh into the outer net from where they are collected by scooping. The fry are transferred to nursery cages where they are reared to fingerling size for about one month.

A grading system is used by the industry for sorting fry and fingerling sizes to minimize mortality from predation or save time during sale. The fish are graded by passing through various mesh sizes of a wire screen or net immersed in water. In land-based systems, the fry/fingerlings are given supplemental feeding using commercially available diets with 30-45 per cent crude protein content at 10-20 per cent of body weight for fry and 5-10 per cent of body weight for fingerlings.

3. PROBLEMS AND OPPORTUNITIES IN INLAND FISHERIES: THE CASE OF LAGUNA DE BAY

Laguna de Bay, the Philippines' largest and most important lake, is located in the most economically dynamic but ecologically vulnerable part of the country. Its 220-km shoreline borders the Metropolitan Manila area at its west bay and the rapidly developing urban and rural areas at its central and east bays (Fig. 4).

It is a multi-use resource, serving as fishing ground; medium of transport and navigation; sink for various waste and effluent discharges from industrial, agricultural, and domestic sources; and source of cooling water for power plants, of irrigation water for agriculture, and of drinking water for Metro Manila residents.

It is 90,000 ha in area and is shallow, with a mean depth of 2.5-3.0 m. It has a single outlet, the Napindan Channel, which joins the Marikina River to form the Pasig River that discharges into Manila Bay. The lake elevation is very close to sea level. Thus, during the dry summer months when lakewater level is low, saline water from Manila Bay flows into Laguna de Bay, bringing salinity levels in the areas close to Pasig River to as high as 4-5 ppt (Baluyut *et al.*, 1981).

The lake is highly eutrophic with primary productivity levels of as high as 1,700 mg C/cu m/hr measured in the late seventies (Baluyut, 1983). (Nutrients such as nitrogen and phosphorus enrich the water from various activities in the watershed: the northwestern portion is highly urbanized and industrialized; the southern portion is mostly agricultural.)

The primary production of the lake (i.e., the production of phytoplankton) varies from year to year, depending on a number of factors, the most important being water transparency/turbidity, temperature, and wind velocity. During the summer months when water temperature and transparency are high, light penetration is good, and wind

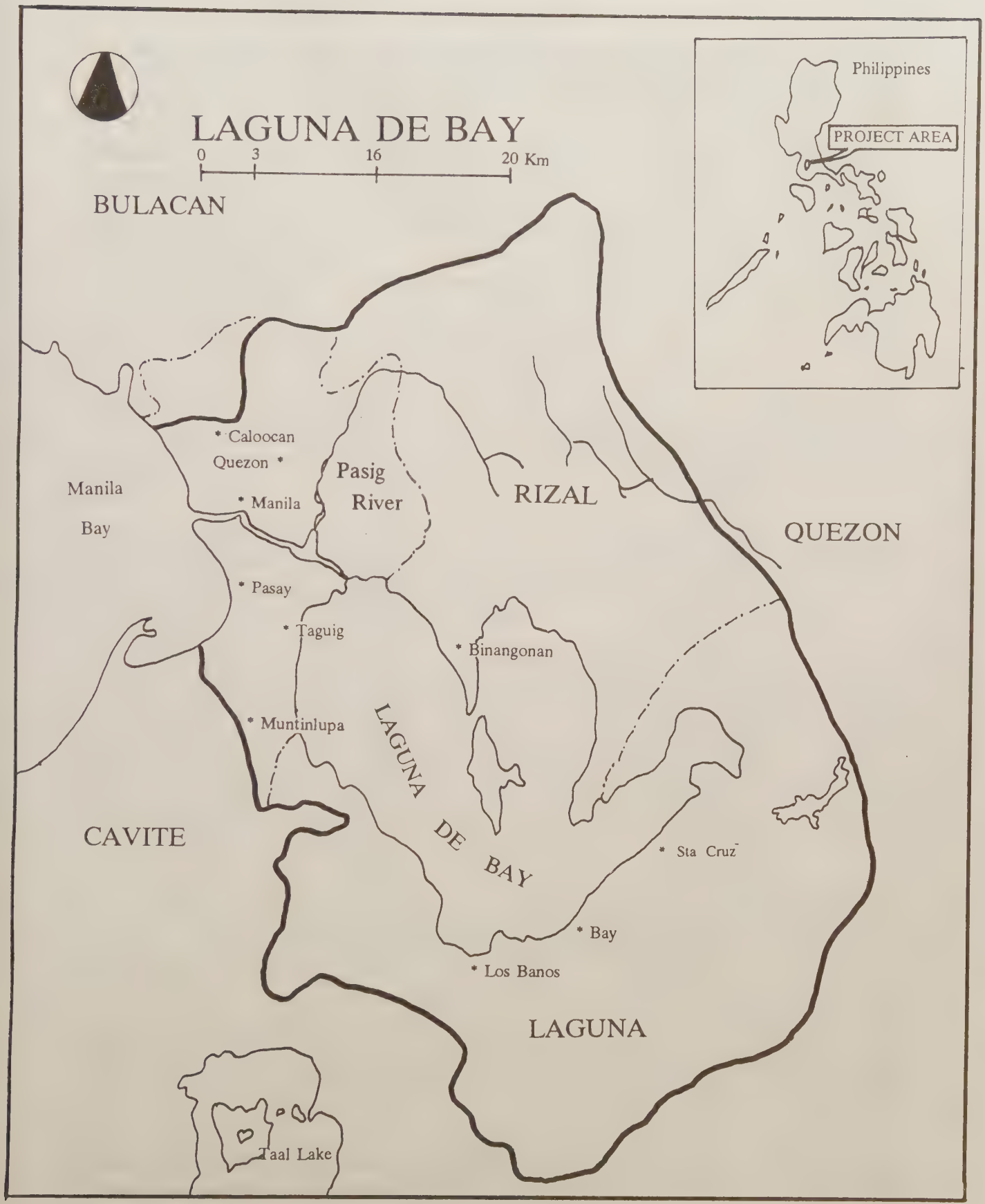

Fig. 4. Map of Laguna de Bay showing its geographical location and its linkage to Manila Bay.

velocity is low, phytoplankton densities, especially of the blue-green and green algae, are high. In some instances, fishkills due to mass die-offs of the blue-green alga *Microcystis aeruginosa* have been reported (Barica, 1976; Beveridge, 1984).

Prior to 1970, the lake was utilized primarily for open water fishing. From 1961 to 1964, the commercial fishery of the lake consisted of finfish, shrimps, and molluscs, mainly clams and snails, the bulk of which was used for animal feeds (only 15 per cent was for human consumption) (Davies *et al.*, n.d.). There were 23 species of fish caught in Laguna de Bay, the dominant species being the freshwater goby, perch, catfish, snakehead, and an indigenous freshwater catfish, *Arius manilensis* (locally known as *kanduli*) (Table 6).

Table 6
Fish species found in Laguna de Bay (from Baluyut, 1983)

Fish species (scientific name)	Common name
Anabas testudineus a/	climbing perch
Anguilla sp. b/	eel
Arius manilensis	sea catfish
Caranx sp.	caranx
Chanos chanos a/	milkfish
Chronophorus melanocephalus	rock goby
Clarias sp.	catfish
Cyprinus carpio a/	common carp
Hemirhamphus sp.	halfbeak
Glossogobius biocellatus	sleeping goby
Glossogobius giurus	white goby
Megalops cyprinoides b/	tarpon
Microgobius lacustris	goby
Mugil sp. b/	mullet
Ophicephalus striatus	catfish
Ophiocara aporos	sleeper
Puntius javanicus a/	tawes
Scatophagus argus b/	spadefish
Tawnioides sp.	eel goby
Therapon plumbeus	therapon
Tilapia spp.	tilapia
Trichogaster pectoralis a/	snakehead gouramy
Trichogaster trichopterus a/	three-spot gouramy

a/ Introduced species
b/ Migratory species

Since most of the fish harvested from the lake were small and of low market value, a UNDP-funded study done in 1968 recommended that fish of a high quality be introduced into the lake for human consumption (Davies *et al.*, n.d.).

In 1970, the Laguna Lake Development Authority (LLDA), after initial experimentation trials, set up a 38-ha pilot fishpen culture project in Looc, Cardona, Rizal within the Central Bay of the Lake. Milkfish (*Chanos chanos*) was used since it was a popular species with high market value. It was also ideal for culture since it is herbivorous, feeding directly on the phytoplankton abundant in the water.

The LLDA Fishpen Project was very successful, demonstrating yields of four mt/ha/yr and changing the concept of Laguna de Bay as a fishery resource (Delmendo and Gedney, 1974). Encouraged by the results of the LLDA Project, many local businessmen and entrepreneurs from outside the Region invested in fishpen culture.

At about the same time that fishpens were being built at a fast pace, tilapia cage culture was developed and grew side by side with milkfish pen culture.

Ancillary businesses were set up and new livelihood opportunities were found. Encouraged by the growing demand for tilapia fry and/or fingerlings, a large number of small, backyard-type, land-based hatcheries were set up around the Lake. [At one point, there were about 200 such hatcheries in the lakeshore towns of Laguna and Rizal provinces (Baluyut, 1988).] Bamboo-gathering, boatbuilding, and trading of *anahaw* poles and other supplies, also became profitable activities as did cage fabrication and net sewing. Lakeshore towns where there were large concentrations of fishpens and cages, experienced an economic boom as a result of tax payments and heavier local spending.

In no time, fishpens and fish cages were all over the lake. From a few hundred hectares in the early seventies to about 4,800 ha in 1973 (Baguilat, 1979), the figures in 1983 were 31,000 ha of disorderly-arranged fishpens (Fig. 5) (Davies *et al.*, n.d.), and about 1,000 ha of fish cages (Guerrero, 1986).

Due to these uncontrolled developments, a number of problems cropped up. Growth of fish slowed down considerably and the rearing period had to be prolonged: from the normal 3-4 months to 8-12 months, even at much lower stocking densities (Lopez, 1990). [In the early years, milkfish yields up to 10 mt/ha/yr were reported from fishpens stocked at 30,000- 40,000 fingerlings/ha/crop; average fishpen yields were put at 4 mt/ha/yr. Tilapia cages stocked at 30-40 fingerlings/sq m/crop yielded about 20 mt/ha/crop (Baluyut, 1983), and repeatable yields of one ton every four to five months from a 216 sq m cage were reported (Pullin, 1981).]

Clearly, the carrying capacity of the lake must have been reached, or perhaps exceeded, and its natural productivity could no longer sustain fish growth. Water circulation was also markedly reduced in congested areas, resulting in a depletion of food organisms leading to poor fish growth (Davies *et al.*, n.d.). Water quality was also noticeably poorer - the water remained turbid, even in the dry summer months, and primary productivity was low. [This decline in water quality and productivity had been attributed in part to the operation of the Napindan Hydraulic Control Structure (HCS) across the Pasig River. It was claimed that keeping the HCS closed prevented the saline waters from Manila Bay to backflow into Laguna Lake (through the Pasig River), especially when the lake level is usually lower than that of Manila Bay, thus preventing the flocculation of suspended solids/particulates by saltwater ions and creating the permanently turbid condition of lake water (Nielsen *et al.*, 1981).]

Fig. 5. Distribution of the 31,000 ha of fishpens in Laguna de Bay in 1983 (from Davies *et al.*, n.d.).

There were various other problems too. Starting in 1986, cases of the epizootic ulcerative syndrome (EUS) were reported during the cooler months of the year (December to February), affecting mostly bottom-dwelling fishes like snakehead and mudfish, possibly as a result of the poor environmental conditions at the lake bottom which may have constituted the "environmental stress factor" precipitating the occurrence of the disease (Baluyut, 1990; Mines and Baluyut, 1987). It is very likely that the proliferation of fishpens and fish cages in the lake had exacerbated the already poor condition of the lake bottom through additional loads of organic matter, mainly in the form of fish excreta and unconsumed feeds. [In an effort to boost production, fishpen operators resorted to supplementary feeding, which, while necessary to improve fish growth, was against all efforts to improve the water quality of the lake (Davies *et al.*, n.d.). In 1985, it was estimated that about 22 t of nitrogen must have been added to the Lake from this source (ERL, 1985).]

Fishpen congestion resulting from the lack of proper management produced other detrimental effects, mostly social in nature. Navigational lanes were blocked by illegally constructed pens and cages. Capture fishermen clashed with fishfarmers over access to the open waters with the former complaining that their fishing grounds have become very much smaller and their incomes very much lower. Poaching became rampant and killings and cases of armed conflict, more frequent. All of a sudden, the problem of social inequity became highly pronounced and the pressure on Government to take action became increasingly heavy. The 1984 LLDA Fishing Zoning and Management Plan (ZOMAP), originally envisioned to serve as a tool to resolve these various conflicts (Baluyut, 1986), somehow turned out to be inadequate for the purpose.

Then in 1986, a number of developments took place in the country that initiated what now seems to be a reversal of the state of affairs in Laguna de Bay.

The February EDSA Revolution and the greater political will of the new leadership enabled the strict implementation of the ZOMAP and the enforcement of the GOP/LLDA policy to limit the fishpen area to a maximum of 20,000 ha, the figure recommended by SOGREAH in 1978.

Illegal fishpen operators (those operating outside the delineated fishpen belt and those operating without licenses) were given notice to dismantle their fishpens/cages or else, these would be demolished by LLDA-led operatives. Government efforts were aided by two big and strong typhoons that passed through Laguna de Bay in close succession in 1987, bringing about large-scale destruction to fishpens and fish cages including those that were built at high cost using structures designed to withstand the impacts of such natural calamities. A large number of these pens and cages were not rehabilitated after the typhoons on account of the high additional investment that would have been required, which would not be recoverable within the short term, given the prevailing environmental conditions in the lake at that time. Other legitimate operators, discouraged by the continued poor performance of their pens/cages, voluntarily dismantled their set-ups or ceased operation.

Today, there are just about 6,500 ha of fishpens and about 263 ha of fish cages in Laguna de Bay and indications are that the lake is undergoing a renewal process (Lopez, pers. comm.). Water quality seems to have improved. Growth of fish in pens and cages has become noticeably faster and the rearing period much shorter (down to 5-6 months from 8- 12 months in the past). Fish production from aquaculture has gone up. And the fishfarmers are much happier and more optimistic about the future. In a very recent tilapia seeding ceremony at the Fish Sanctuary in Talim Island, a group of small fishermen were said to have told the Director-General of the National Economic and Development Authority (NEDA) how glad they were that "Laguna Lake seems to be alive again" (Lopez, pers. comm.).

4. SUMMARY AND CONCLUSIONS: THE CASE FOR TILAPIA IN INLAND WATER MANAGEMENT

In the Philippines, tilapia has proven to be an effective tool for the efficient management of inland waters. Be it through the stocking and/or introduction of the fish in open waters, lakes or reservoirs, or through its culture in enclosures within these freshwater bodies, it has been shown that the use of tilapia is a practical strategy towards attaining the improved utilization of a waterbody as a fisheries resource.

No doubt, tilapia cage culture, despite problems encountered in the past, offers great opportunities for increased food supply as well as for socio-economic development, particularly for the rural and more depressed areas in the country, on account of a number of factors.

One, it is not capital-intensive and is high-yielding. The low initial capital investment for tilapia cage culture makes it highly suitable for small-scale producers. Moreover, credit support is available from Government programs that encourage such livelihood enterprises, e.g., the Livelihood Enhancement for Agricultural Development (LEAD) Program of the Department of Agriculture (DA)/National Agriculture and Fishery Council (NAFC), and the *Kabisig* Fund of the Office of the President.

Two, it uses simple technology that is easy to transfer to the rural areas and can utilize family labor in its operations. This also means that it is a highly attractive source of supplemental income for households in the countryside areas. For example, while investment costs have risen considerably, the LLDA estimates that a family can make a net income of ₱12,450/yr from a 1,000-cu m floating cage in Sampaloc Lake (Lopez, 1990).

Three, if properly managed and controlled, it is "environment-compatible" and does not pose great hazards to ecological stability or environmental quality. It is also relatively low-risk and less prone to the negative effects of natural occurrences like typhoons.

While this is the case, however, efforts need to be continuously exerted if the further development and expansion of the industry is to be attained.

Firstly, it is necessary to pursue and expand the action initiated by the International Center for Living Aquatic Resources Management (ICLARM) and the Central Luzon State University (CLSU) towards the genetic improvement of tilapia stocks. This is imperative in view of the problem of genetic aberration resulting from the deterioration of broodstock due to the interbreeding of tilapia species both in the wild and in culture leading to slow growth and body deformities among the progenies.

There is also a need to ensure an adequate supply of high-quality fry for stocking in open waters or for culture in cages. While there are hundreds of tilapia hatcheries in the Philippines, not many are able to supply good-quality fry and fingerlings since the small hatchery operators do not pay attention to, or may simply be unaware of, the need to constantly change or upgrade breeder stock to prevent inbreeding and its consequent problems. Also, in other areas of the country, there is a shortage of tilapia hatcheries to supply tilapia seedstock. This may be reflective of an inadequate technology dissemination and extension program on the part of Government or the lack of capital to start hatchery operations, or both.

In some other cases, tilapia cage culture projects have failed due to the absence of prior research and development work with focus on technology refinement or adaptation. For example, had feeding trials been conducted at the Pantabangan Reservoir prior to the commercial-scale implementation of a tilapia cage culture project, the fishfarmers would have known that, unlike in Laguna de Bay, they need to feed their fish for their project to succeed. Greater effort also needs to be exerted towards the formulation of efficient yet economical feeds for tilapia.

Finally, a system of effective regulation of, and control over, the establishment of fishpens and fish cages in inland waterbodies, has to be put in place and enforced by Government in order to prevent negative experiences similar to those in Laguna de Bay. Those concerned need to have the political will necessary for the proper management and utilization of the country's inland waters.

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CICHLIDAE VERSUS CYPRINIDAE: EXPERIENCE FROM THE INLAND FISHERY OF SRI LANKA

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1. INTRODUCTION

Sri Lanka has a relatively depauperate freshwater fish fauna with only 65 species as compared to its neighboring countries like Malaysia and Thailand (Fernando, 1977; Pethiyagoda, 1991). However, the occurrence of 41 fish species in reservoirs out of the total number indicates a high diversity as compared to any habitat (Fernando, 1991a). The family Cyprinidae, consisting of 33 species (Pethiyagoda, 1991), is best represented in the freshwater fish fauna of the country. However, the inland fish production of Sri Lanka, which comes from its multitude of reservoir systems, is based on the exotic cichlid species.

Various workers in the country have dealt with the use of cyprinids and cichlids in inland fisheries management in Sri Lanka. De Silva (1987) examined the role of exotic species in relation to indigenous fish resources. Sreenivasan and Thayaparan (1983) advocated the stocking of major perennial reservoirs with Indian major carps. Sreenivasan (1989) and Jayasekara (1989), reported that the stocking of fingerlings of Chinese and Indian carps has actually been intensified in Sri Lanka. De Silva (1987, 1988) suggested that Chinese and Indian carps are more suitable for fish culture in seasonal tanks (i.e., non-perennial, small village reservoirs) and ponds rather than in the large perennial reservoirs. Also, the indigenous small-sized cyprinid species, often termed as minor cyprinids to distinguish them from Indian major carps and Chinese carps, support a subsidiary fishery in perennial reservoirs (De Silva and Sirisena, 1987, 1989; Sirisena and De Silva, 1988, 1989; Amarasinghe, 1990). Fernando (1991b) suggested that the yields from the indigenous cyprinid fishery have been apparently enhanced by the presence of the herbivorous tilapias in the reservoirs.

This paper attempts to evaluate the advantages and disadvantages of using cichlids and cyprinids as tools for the further development of the inland fisheries of Sri Lanka.

2. CICHLIDS AND CYPRINIDS IN CAPTURE FISHERIES

Some 41 species of fish have been reported to occur in Sri Lankan reservoirs, of which 23 are listed in Table 1, including 18 cyprinid and five cichlid species. Among the cyprinids, three indigenous species and seven introduced species are recorded to be caught in the commercial fisheries in reservoirs. In addition, eight species of minor cyprinids are found in the reservoir fish fauna but are not commercially exploited at present.

Table 1
List of cichlid and cyprinid species in the inland capture and culture fisheries in Sri Lanka.

Family/Species	Maximum recorded length (cm)	Remarks
Cichlidae		
Oreochromis mossambicus (i)	44	Very important in the inland capture fishery.
O. niloticus (i)	54	Dominant in some reservoirs; used for cage culture experiments.
Tilapia rendalli (i)	36	Important food fish caught in the inland fishery.
Etroplus suratensis	28	Transplanted from lagoons; important food fish.
E. maculatus	8	Caught in small-mesh experimental gillnets; an ornamental fish species.
Cyprinidae		
Amblypharyngodon melettinus	7.5	Caught in experimental nets; abundant in most reservoirs.
Danio aequipinnatus	7.5	Caught in experimental nets.
Esomus dandrica thremoicos	6.25	–do–
Rasbora daniconius	10	–do–
Barbus ticto	5	–do–
B. chola	8.75	Caught in experimental nets; abundant in most reservoirs.
B. filamentosus	11.75	–do–
B. dorsalis	23.5	–do–
B. sarana	30	Important in the inland capture fishery.
Labeo dussumieri	35	–do–
L. rohita (i)	75	Occasionally caught in reservoirs; do not breed naturally. Used in seasonal tanks.
Cirrhinus mrigala (i)	75	–do–
Catla catla	65	–do–
Ctenopharyngodon idella (i)	90	–do–
Hypophthalmichthys molitrix (i)	100	–do–
Aristichthys nobilis (i)	60	–do–
Cyprinus carpio (i)	60	–do–
Tor khudree longispinis	75	Caught in up-country reservoirs.

i = introduced species.

Among the cichlids, *Oreochromis mossambicus* and *O. niloticus* are the most important and constitute the base of the country's inland fisheries. Prior to the introduction of *O. mossambicus* in 1952, fish production in Sri Lankan reservoirs was very low.

2.1 Cichlids in the Reservoir Fishery

The family Cichlidae has made a significant sociological impact in Sri Lanka due to the unprecedented success of the exotic *O. mossambicus* in the inland fishery. Records show that the percentage contribution of *O. mossambicus* to the fishery of major perennial reservoirs ranged between 56 and 99 per cent and that in most

reservoirs, this species accounted for more than 70 per cent of the landings (De Silva, 1985a). This colonization success of *O. mossambicus* is said to be due to a number of reasons including the absence of true lacustrine-adapted indigenous species in the reservoirs prior to its introduction (Fernando and Holcik, 1982 and 1989; Fernando, 1984) and the availability of a variety of food sources of high nutritive quality favorable for its growth (De Silva *et al.*, 1984 b; Maitipe and De Silva, 1985; De Silva, 1985b; De Silva *et al.*, 1988).

More recently, however, increasing proportions of *O. niloticus* have been observed in the catches of some reservoirs; e.g., Soraborawewa (Chandrasoma, 1986a), Parakrama Samudra (Amarasinghe, in press), and Kandulla and Tabbowa (Amarasinghe, 1988) (Figs. 1 and 2). In Kotmale and Victoria, two recently impounded reservoirs, *O. niloticus* accounts for 33.2 and 15.8 per cent of the landings, respectively (De Silva, in press).

The reason for this dominance is not clear, however. While Chandrasoma (1986a) suggested that it could be due to the abundance of blue-green algae, its preferred food, De Silva (1988) is of the belief that since *O. mossambicus* could also utilize blue-greens, although not as efficiently as *O. niloticus*, the reason given is not adequate to explain the dominance of *O. niloticus*. This view seems to be supported by a report that the relative abundance of blue-green algae in Kotmale reservoir, where *O. niloticus* is dominant, is not significantly different from that of two other up-country reservoirs where *O. mossambicus* is dominant (De Silva, in press).

It is possible that the dominance of *O. niloticus* in some reservoirs could be attributed to genetic factors. The continued introduction of *O. niloticus* in reservoirs with stocks of *O. mossambicus* may have resulted in hybridization as manifested, for example, by phenotypic color variations in these two species in certain parts of the country. In *O. niloticus* stocks in southern reservoirs, a high degree of introgression of *O. mossambicus* alleles has been reported (De Silva and Ranasinghe, 1989).

The inter-specific competition between *O. mossambicus* and *O. niloticus* for nesting sites and food may be another reason for the success of the latter in reservoirs considering that the former is disadvantaged by stunting. In an evaluation of past and recent data on growth, size at maturity, and mean landing sizes of *O. mossambicus* in Sri Lankan reservoirs, De Silva and Amarasinghe (1988) found that most populations exhibit both stunted and non-stunted features corresponding to "r-selected" and "k-selected" lifestyles, respectively (Pianka, 1971). Furthermore, it has been observed that clustering of nests of similar sizes in a reservoir is possibly related to the size of brooding fish (De Silva and Sirisena, 1988). Thus, in a reservoir with stunted *O. mossambicus* and *O. niloticus* in which introgression of *O. mossambicus* alleles has taken place, hybrids of *O. mossambicus* and *O. niloticus* are likely to be dominant.

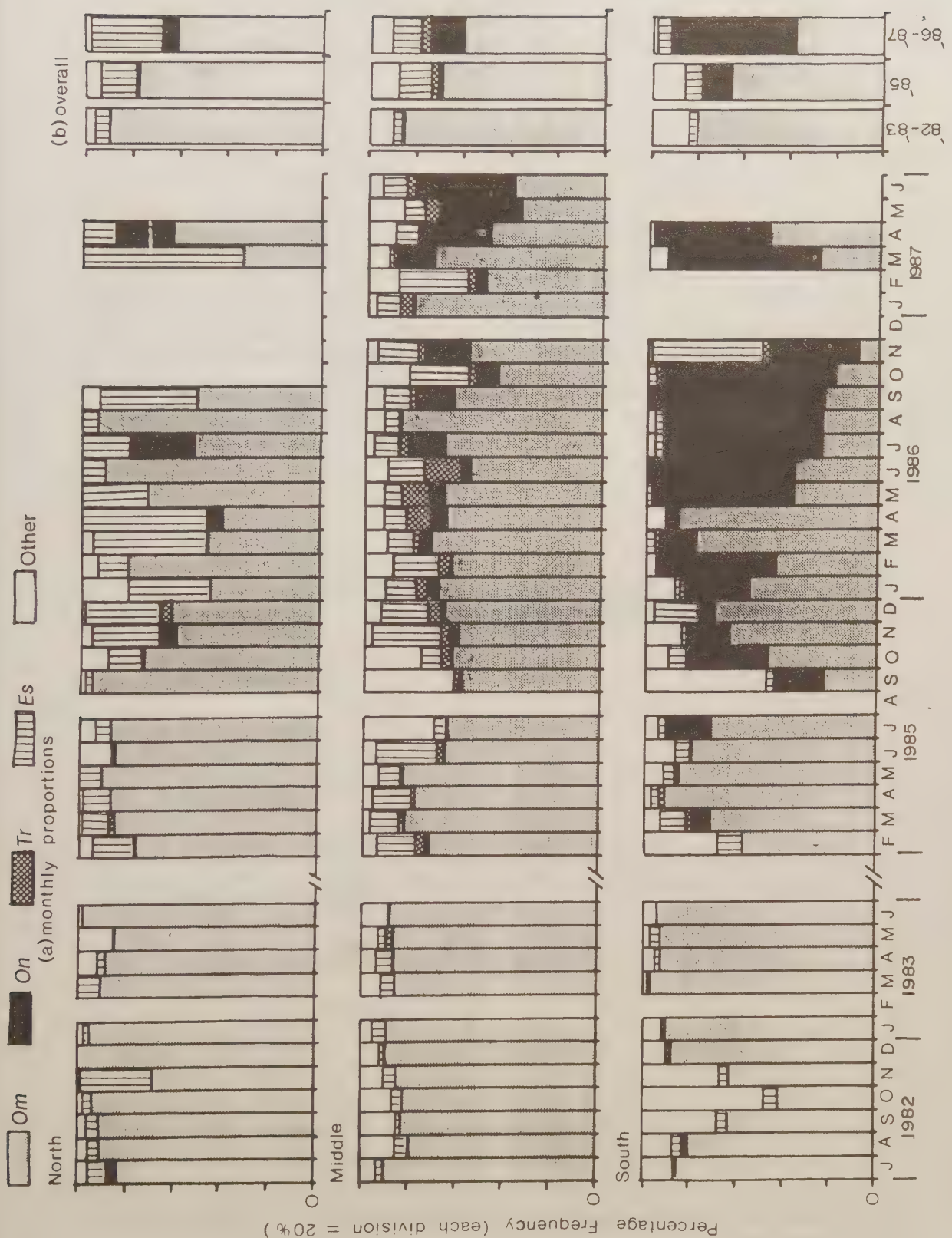

Fig. 1. Monthly (a) and overall (b) percentages species composition of the commercial catches in Parakrama Samudra, a Sri Lankan reservoir (from Amarasinghe, in press). (*Om - O. mossambicus*; *On - O. niloticus*; *Tr - T. rendalli*; *Es - E. surantensis*.)

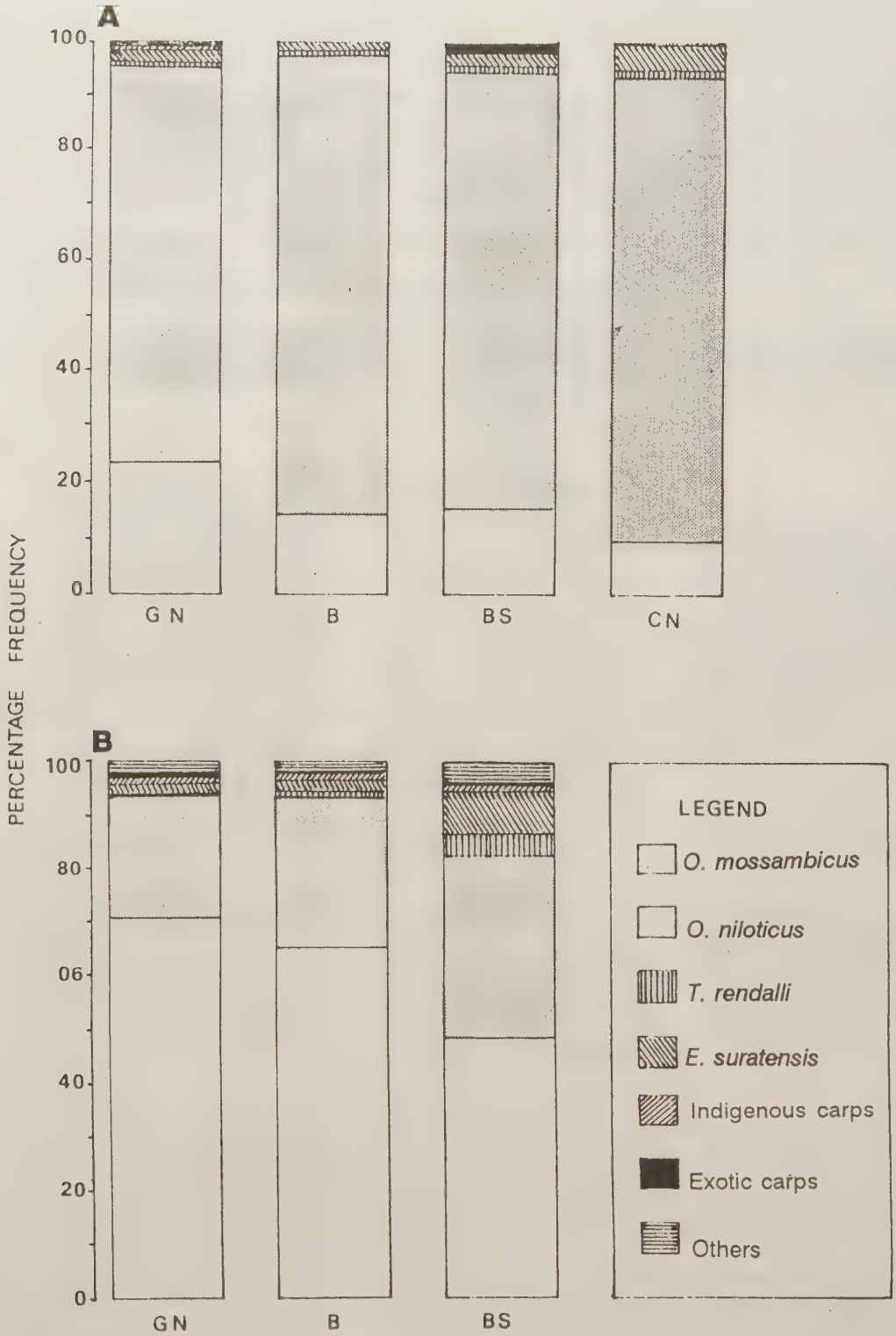

Fig. 2. Species composition (%) of landings in two Sri Lankan reservoirs (A - Kandulla; B - Minneriya), 1986-1989 (Amarasinghe, unpublished). GN - Gillnetting; B- Water beating, a modified gillnet fishing method to drive fishes towards nets (Amarasinghe and Pitcher, 1986); BS - Beach seining; CN - Cast netting.

2.2 Cyprinids in the Reservoir Fishery

All indigenous cyprinid species found in Sri Lankan reservoirs are drawn from rivers; the introduced cyprinids caught in reservoirs are Indian and Chinese carps (refer back to Table 1).

Two indigenous cyprinid species, *Labeo dussumieri* and *Barbus sarana*, which used to contribute significantly to the commercial catches in reservoirs, particularly during rainy seasons (De Silva, 1983), have become less important in the more recent past (Table 2). The significant reduction in percentage contribution of these two species to total landings may be attributed to the adverse effects of river damming on their reproductive behavior. Smith and Jiffry (1986) suggested that the completion of three major dams in the upper catchment of the Mahaweli river would radically alter the downstream areas and would lead to a decrease in the northeast monsoon spawners of *L. dussumieri*, thereby decreasing the overall population and production of this species. Furthermore, when the highly productive target species, *O. mossambicus*, is exploited, less productive species such as *L. dussumieri* and *B. sarana*, which are exploited from the same gear, are likely to be overexploited.

Table 2
Percentage contribution of *L. dussumieri* and *Barbus* spp. to the commercial landings in Parakrama Samudra (adopted from Amarasinghe, 1989).

	Total catch (mt)	Percentage contribution		Source
		L. dussumier	Barbus spp.	
1964 September				
Beach seines	1.8	21.7	-	Fernando (1967)
Gillnets	38.6	8.0	0.6	-do-
1964 October				
Beach seines	1.7	18.6	3.4	-do-
Gillnets	45.3	19.3	0.5	-do-
1964 November				
Beach seines	49.4	2.2	0.6	-do-
Gillnets	36.6	23.5	0.4	-do-
1964 December				
Beach seines	13.3	15.7	1.2	-do-
Gillnets	35.7	40.7	0.2	-do-
1985-86				
Gillnets	122.7	2.2	0.9	Amarasinghe & Samarakoon (1988)

Four species of minor cyprinids (*Amblypharyngodon mellettinus*, *B. dorsalis*, *B. chola*, and *B. filamentosus*) are found in abundance in major reservoirs of the country and could be exploited using small-meshed (15-52 mm) gillnets without affecting the existing *O. mossambicus* fishery (Amarasinghe, 1985; De Silva and Sirisena, 1987). Inasmuch as the fishery potential of minor cyprinids in Sri Lankan reservoirs (Table 3) is appreciably higher than the present annual fish production of 307 kg/ha/yr in reservoirs, the introduction of a new small-meshed gillnet for minor cyprinids has been suggested to enhance fish yields in perennial reservoirs of the country (De Silva, 1989) and provide supplementary income to fishermen on account of their commercial value as dried fish (Amarasinghe, 1990). It may be worthwhile to mention that in the Sri Lankan reservoir fishery, the gillnet is the most important fishing gear since it is virtually impossible to use other types due to the presence of submerged decaying tree stumps. Also, mesh size regulations (7.5 cm) in the reservoir fishery have been imposed by the Ministry of Fisheries to prevent exploitation of small-sized fish species.

Table 3
Fishery potential of minor cyprinids in some reservoirs of Sri Lanka.

Reservoir	Surface Area (ha)	Fishery Potential (kg/ha/yr)	Source
Badagiriya	482	2191	De Silva and Sirisena, 1989
Lunugamwehera	3023	635	- do -
Muruthawela	516	35	- do -
Ridiyagama	888	1234	- do -
Tissawewa	234	679	- do -
Yodawewa	488	688	- do -
Parakrama Samudra	2262	632	Amarasinghe, 1990

All the introduced major carps are sub-tropical and none of them, except for common carp (*Cyprinus carpio*), have established breeding populations south of 11°25'N (De Silva, 1988). As Sri Lanka lies further south than 11°25'N and is also unlikely to provide the complicated and little understood conditions needed for natural spawning found in large river systems (Sinha *et al.*, 1974), the major carps could not be expected to establish naturally breeding populations in Sri Lanka (De Silva, 1988).

Thus, during the last three decades, the Ministry of Fisheries had stocked the reservoirs with hatchery-reared fingerlings of major carps with a view to establishing a stocking-recapture fishery. However, the contribution of exotic carps to the reservoir fishery has been insignificant, particularly in large reservoirs (> 1000 ha) (Table 4; Fig. 2). This may be due to the fact that unlike in countries like China where the stocking-recapture fisheries are well-planned and successfully practised (De Silva *et al.*, 1991),

that in Sri Lankan perennial reservoirs is not scientifically planned. Also, due to the limited nursery pond area available in fish breeding stations, it is extremely difficult to raise fingerlings to the right size for stocking (ca. 10 cm). As a result, small-sized fingerlings (5 cm) are used. (In Chinese reservoirs, carp fingerlings for stocking range from 10-13 cm in size.) Moreover, stocking densities are very low and natural mortality rates are high due to predation by carnivorous fish species (De Silva and Fernando, 1980; Silva and Davies, 1987) and piscivorous birds (Winkler, 1983).

Table 4
Recovery of carps stocked in selected reservoirs of Sri Lanka. (modified from Hettiarachchi, 1990).

Reservoir	Species	Total quantity stocked (individuals), 1983-87	Stocking density (individual/ha)	Total catch (mt), 1984-88	Number of fish recovered	% recovery
Giritale	Bighead	365,000	1,185	89.3	29,800	8.2
(308 ha)	Common carp	11,000	36	5.0	1,700	15.5
	Mrigal	56,000	182	12.9	4,300	7.7
	Rohu	148,000	481	38.5	12,900	8.7
	Silver carp	25,000	81	-	-	-
Kaudulla	Catla	4,000	1.5	-	-	-
(2713 ha)	Common carp	4,000	1.5	-	-	-
	Rohu	10,000	4	-	-	-
Maduru Oya	Bighead	131,000	21	3.5	1,200	0.9
(6280 ha)	Common carp	24,000	4	-	-	-
	Rohu	60,000	10	-	-	-
Minneriya	Bighead	90,000	35	72.6	24,200	26.9
(2551 ha)	Mrigal	34,000	13	10.6	3,500	10.3
	Rohu	135,000	53	58.2	19,400	14.4
Parakrama	Bighead	64,000	28	-	-	-
Samudra	Catla	10,000	4	7.4	2,500	25.0
(2262 ha)	Common carp	92,000	41	-	-	-
	Rohu	304,000	134	61.4	20,500	6.7
Pimburettewa	Bighead	6,000	7	-	-	-
(830 ha)	Catla	2,000	2.4	2.2	730	36.5
	Common carp	72,000	87	1.0	300	0.4
	Mrigal	128,000	154	2.9	1,000	6.2
	Rohu	34,000	41	13.5	4,500	13.2
	Silver carp	86,000	104	36.6	12,200	14.1

Note: The weight of an average fish harvested has been assumed to be 3 kg.

In medium-sized reservoirs (<1000 ha) where stocking densities are appreciably higher than those in large reservoirs, fish yields have been considerably enhanced by stocking of exotic carps (Table 4). This suggests that if the stocking program using fingerlings of major carps is well-planned, reasonable increases in total yield can be achieved. However, the benefits of such a stocking-recapture fishery in medium-sized reservoirs have to be weighed against alternative methods of increasing fish yields in inland waters using major carps, e.g., fish culture in seasonal tanks.

As stated by De Silva (1988), all strategies adopted to increase fish yield should aim at providing animal protein at the lowest possible price and not at providing a diversity of table fish. Also, in view of the low returns from stocking of Indian major carps and Chinese carps, attempts to establish a stocking-recapture fishery in major perennial reservoirs of Sri Lanka seem to be illogical (De Silva, 1988). Even if it is argued that yields from the stocking-recapture fishery based on major carps could be increased by employing highly efficient fishing methods such as those practised in Chinese reservoirs (De Silva *et al.*, 1991), it may not be worth pursuing if it is considered that doing so could lead to the overexploitation of the cichlid fish stocks which sustain a self-established, profitable fishery.

3. CICHLIDS AND CYPRINIDS IN THE CULTURE FISHERY

Freshwater fish culture is not well-developed in Sri Lanka. Until 1990, the Ministry of Fisheries provided subsidies in the form of financial assistance and fingerlings in an attempt to promote fish culture in ponds. Until the end of 1983, over 1,500 freshwater ponds were constructed for fish culture under the subsidy scheme (Chakrabarty, 1983). However, no proper scientific studies were carried out on the selection of suitable sites and suitable species for culture of fish in ponds, among others.

In freshwater fishponds, the species cultured are *O. mossambicus*, *O. niloticus*, bighead carp, grass carp, and common carp. At stocking densities varying from 3,000 fingerlings/ha to as high as over 20,000 fingerlings/ha, fish yields obtained ranged from 200-500 kg/ha, with no significantly higher yields even at the higher stocking densities (Chakrabarty, 1983; Sreenivasan, 1967).

Experimental trials on cage culture and fish culture in seasonal tanks have also been carried out in Sri Lanka.

3.1 Culture Performance of Cichlid Species

Unlike in India where *O. mossambicus* is considered a pest because of its effects on carp culture in ponds, the tilapias did not produce any adverse impacts on carps in Sri Lanka. In seasonal tanks where only Chinese and Indian carps were used for polyculture, tilapias were recorded to contribute considerably to the final harvest (Chandrasoma and Kumarasiri, 1986). Furthermore, preliminary cage culture trials using both major carps and *O. niloticus* showed that *O. niloticus* is more suitable for cage culture than the Chinese and Indian carps which showed a poor growth in cages possibly due to low plankton productivity, the small initial size of fingerlings, inadequacy of supplementary feed, and a high incidence of diseases (Muthukumarana and Weerakoon, 1988).

In some shrimp farms with a salinity of 5-25 ppt and where fish eradicating agents such as saponin are not used, tilapia is a "by-catch" in the harvest, as has been the experience of Levers Aqua Products, which gets about 500 kg of tilapia per harvest at a mean size at harvest of 18 cm after a culture period of about four months (Kanakaratne, pers. comm.).

Based on results of fish culture practices in Sri Lanka and considering that tilapia has a high consumer preference, incorporating tilapias in polyculture of fish in ponds and seasonal tanks could be a good strategy for achieving high fish yields. Of the tilapia species, however, *O. niloticus* may be more suitable since it does not exhibit stunting like *O. mossambicus* (Moreau *et al.*, 1986; Pauly *et al.*, 1988). Moreover, it has been shown that the ratio of catchment area to reservoir area, or the "Index of Allochthonous Input", and the size of maturity of *O. mossambicus* has a negative log-linear relationship, suggesting that *O. mossambicus* may not be the most suitable species for culture in small waterbodies such as ponds and seasonal tanks (De Silva and Amarasinghe, 1989).

3.2 Performance of Cyprinid Species under Culture

Polyculture of different species of Chinese and Indian major carps is said to be an efficient method for achieving high yields through utilization of different niches in culture systems such as fish ponds (Bardach *et al.*, 1972). In Sri Lanka, Chinese and Indian carps have been cultured in seasonal tanks and in ponds, largely on an experimental basis.

Chandrasoma and Kumarasiri (1986) and Chandrasoma (1986b) reported the successful culture of Chinese and Indian carps in seasonal tanks and attributed this to the availability of different types of natural food and the high primary productivity in the tanks (Table 5). However, as carps cannot occupy all niches in the ecosystem, incorporating tilapias in fish culture programs in seasonal tanks is useful to achieve high yields, especially in view of the ability of *O. mossambicus* and *O. niloticus* to digest blue-green algae (Costa and Abeysiri, 1978; Moriarty, 1973; Moriarty and Moriarty, 1973).

Table 5
Some physico-chemical and biological characteristics and fish yields in seasonal tanks in Sri Lanka (from Chandrasoma, 1986)

Surface dissolved oxygen (mg/l)	2.5 - 10.3
pH	6.9 - 8.7
Conductivity (umhos/cm)	50 - 950
Secchi disc visibility (cm)	30 - 110
Chlorophyll-a (ug/l)	5.24 - 145.65
Free carbon dioxide (mg/l)	0 - 20
Total alkalinity (mg/l)	20 - 310
Primary productivity (g C/m2/day)	1.995 - 11.34
Fish yield (kg/ha)	219.8 - 2303.5

In contrast to the successful commercial culture of carps in seasonal tanks, that in ponds is still in the experimental stage. Also, while trials at the MOF fish breeding stations have shown the technical feasibility of pond culture on account of the fast growth and low mortality of the carps (Weerakoon, 1979; Balasuriya *et al.*, 1983; Tennakoon *et al.*, 1988), no attempts have yet been made to investigate its economic feasibility considering the cost of carp fingerling production, pond construction and maintenance, and value of harvest. Fernando (1980) is of the view that carp culture in ponds will not be economically feasible in Sri Lanka.

Induced breeding of the indigenous cyprinid *L. dussumieri* has been successful (Balasuriya, 1982) but is of little use for the culture fishery of Sri Lanka due to the slow growth rate of the fish.

4. POSSIBLE INTERACTIONS BETWEEN CICHLIDAE AND CYPRINIDAE

The co-occurrence of cichlid and cyprinid species in perennial reservoirs and the equilibrium levels of different fish stocks are determined, among others, by the interactions among different species. Fernando (1984) indicated that before the introduction of *O. mossambicus* in 1952, fish yields in reservoirs in Sri Lanka were very low. While evidence from different parts of the world indicate that in man-made lakes, indigenous species alone could not support profitable fisheries because of their inability to successfully colonize lacustrine habitats in these reservoirs (Fernando and Holcik, 1982, 1985, 1987, 1989) this does not seem to be the case in Sri Lankan reservoirs where indigenous minor cyprinids occur in abundance. This is perhaps the result of a new equilibrium that has taken place after the introduction of *O. mossambicus* (Fernando, 1967; Schiemer and Hofer, 1983; De Silva and Sirisena, 1987, 1989; Amarasinghe, 1990), which may in turn be related to the abundance of blue-green algae in Sri Lankan reservoirs (Amarasinghe *et al.*, 1983; Daniel *et al.*, 1989) and the ability of the tilapias to digest them (Costa and Abeysiri, 1978; Moriarty, 1973; Moriarty and Moriarty, 1973). Since *O. mossambicus* and *O. niloticus* are the only species in Sri Lankan reservoirs which can digest blue-green algae, their presence in the reservoirs is useful in speeding up the mineralization process (De Silva and Fernando, 1980; Fernando, 1991b). As a result, the indigenous fish species, especially the cyprinids, are possibly benefitted by the improved trophic status of the reservoirs.

While the minor cyprinids abound in Sri Lankan reservoirs, populations of the larger indigenous cyprinids like *L. dussumieri* have been declining, possibly as a consequence of river damming and overexploitation. The larger indigenous cyprinids breed in shallow areas of flood waters bordering rivers and streams (Chandrasoma and De Silva, 1981; De Silva, 1983; Smith and Jiffry, 1986). On the other hand, the minor cyprinids, which are inhabitants of rivers, have invaded the lacustrine habitats in reservoirs. Although they may also not breed within the reservoirs, the young stages of minor cyprinids such as *B. filamentosus* have been found in littoral areas of reservoirs (personal observations) so that the minor cyprinids could perhaps breed in small streams flowing into reservoirs.

As shown in Table 6, the food habits of some species seem to overlap. For example, *O. mossambicus* and *A. melettinus* feed on similar kinds of food except for the intake of blue-green algae by *O. mossambicus* (Schiemer and Hofer, 1983). Food habits of *B. chola* and *B. dorsalis* are also similar. Nevertheless, peak feeding periods of these two species do not overlap: *B. dorsalis* feeds during the night and *B. chola*, throughout the day. Also, *B. dorsalis* has a tendency for inshore migration during the period of its highest feeding intensity (Schiemer and Hofer, 1983). Due to this spatial segregation of the two cyprinids, their food competition is relaxed to an extent (Schiemer and Duncan, 1983).

Table 6

Major components of food of commercially important cichlids in the reservoir fishery and abundant indigenous cyprinids in major reservoirs. (The number of crosses indicates the importance of the food component).

Family/Species	Food component							Source
	1	2	3	4	5	6	7	
Cichlidae								
O. mossambicus	++	++	+		++	++		a, b, d, g
O. niloticus	++	++	+					various authors
T. rendalli		+	+	++				various authors
E. suratensis		+	+	++	+	+		e, f
Cyprinidae								
A. melettinus		++	++					b, c
B. dorsalis				+	+	++		b, c
B. chola				+	+	++		b, c
B. filamentosus		++					+	b, c
R. daniconius		+				++	+	b, c

Legend:

1 – Blue green algae
2 – Green algae
3 – Diatoms
4 – Macrophytes
5 – Detritus
6 – Invertebrates
7 – Fish

a – Costa and Abeysiri, 1978;
b – Hofer and Schiemer, 1981;
c – Schiemer and Hofer, 1983;
d – Dokulil, 1983;
e – Costa, 1983;
f – De Silva *et al., 1984b;*
g – Maitipe and De Silva, 1985.

5. SUMMARY AND CONCLUSIONS: FUTURE STRATEGIES FOR MANAGEMENT

In view of the importance of cichlids to the country's inland fisheries, future strategies for fisheries management would necessarily involve their use both as capture and culture species.

A number of concerns need to be looked into in this respect. For one, the effect of introgressive hybridization between *O. mossambicus* and *O. niloticus* on the reservoir capture fishery should be investigated in detail. It has been shown that the *O. mossambicus* populations in two Sri Lankan reservoirs show higher growth performance than those in other localities, possibly due to hybridization (Amarasinghe and De Silva, in press), availability of a variety of food sources of high nutritive quality (De Silva, 1985b), and/or a combination of these factors, suggesting that for fish culture in ponds, seasonal tanks and cages, *O. mossambicus* and *O. niloticus* hybrids could be used for better yields. In this connection, studies on genetic improvement and monosex culture of tilapia should also be undertaken.

Secondly, as it has been shown that water regimes in reservoirs have a positive influence on the abundance of cichlid species (De Silva, 1985c; Blay and Amarasinghe, unpublished), future management strategies could be directed towards the establishment of a close link between irrigational water management in reservoirs and fishing activities.

Thirdly, it has been shown that modifications of surplus yield models could be used to predict yields and estimate optimal fishing strategies in reservoirs (De Silva *et al.*, in press). Also, length-based stock assessment procedures have been successfully employed to study the status of individual reservoir fisheries (Amarasinghe, 1987; Amarasinghe *et al.*, 1989; Amarasinghe and De Silva, in press). The optimal exploitation levels in individual reservoir fisheries could be defined which in turn could be used to manage the reservoir capture fishery by measuring a few simple parameters. For example, the percentage of undersized (below 20 cm) *O. mossambicus* has been used as an index of fishing pressure (Amarasinghe, 1988; De Silva and Amarasinghe, 1989).

Finally, inasmuch as the indigenous minor cyprinids could be exploited without a detrimental effect on the cichlid fishery (De Silva and Sirisena, 1987), the introduction of a small-scale subsidiary gillnet fishery for minor cyprinids could be considered as a strategy towards increasing yields. The introduction of a new subsidiary gillnet fishery for minor cyprinids could lead to a new equilibrium due to species association and interaction in the reservoir ecosystem. Further investigations are also needed to determine the ability of minor cyprinids to sustain such a small-scale fishery. The effects of exploitation of one group of fish on other fish species could be investigated through holistic approaches. Recently developed methodologies for parameter estimation for ecosystem modelling are now available (Pauly, 1986; Palomares and Pauly, 1989; Jarre *et al.*, 1990; Christensen and Pauly, 1990), and could greatly assist in reservoir fishery research leading to the formulation of future management strategies.

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CURRENT CONTRIBUTION OF TILAPIA TO CAPTURE FISHERIES IN THAILAND

by

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1. INTRODUCTION

The Nile tilapia, *Oreochromis niloticus*, was first introduced into Thailand on 25 March 1965 when His Royal Highness Prince Akihito of Japan presented 50 fish to His Majesty, the King of Thailand. Recognizing its considerable potential for production and its value as a cheap protein resource for the people, the King then distributed 10,000 fingerlings to the Royal Thai Department of Fisheries for further propagation and distribution in 1966. Due to its fertility and spawning capability, the fish is now an economically important species for various types of aquaculture and for stocking in waterbodies throughout the country.

2. DISTRIBUTION

The good performance of the tilapia in the country makes it a popular introduced species for stocking in public waters. However, in view of its yet unknown impacts on existing fish populations in Thailand, its use as stocking material has been regulated by the Department of Fisheries (DOF), which has ruled that it is not supposed to be released into open water systems of any kind. In spite of this regulation, tilapia can get into waterbodies through flooding and leakages from hatcheries. During the last two decades, floods had swept through many parts of the country including private farms and the hatcheries of Fisheries Stations, such as those in the south (at Surathani and Trang), in the north (at Nan, Phryao, and Chiang Rai), and in the northeast (at Ubolrachatani and Udontani). The fish is also accidentally released into waterbodies through drainage systems of hatcheries and fish ponds, especially those located adjacent to rivers, reservoirs, or public waters. Therefore, tilapia may appear even in waters where the fish has not been stocked.

In 1988, tilapia was reported in the landing records of all provincial impoundments throughout the country, ten years after the start of the Nationwide Fish Stocking Program in 1978 or about 20 years after it was first introduced into Thailand (Department of Fisheries, 1988a).

3. SEED PRODUCTION AND STOCKING PROGRAM

The DOF is the sole producer of tilapia fry and fingerlings to be used for stocking of waterbodies in the country. At present, DOF operates 50 inland fisheries stations equipped with hatcheries which produce Nile tilapia as a major species for stocking. The quantities produced by these stations depend upon their production capacities as well as on the number of seed required for distribution among the waterbodies.

The production of tilapia seed increased from 1.5 million in 1967 to 23.2 million in 1985, declined to 20.3 million in 1986, and has stabilized at around 16 million from 1987 to 1990 (Table 1). Present production of fish seed is limited by various conditions including a reduced demand for the seed and a DOF policy to concentrate on other species of higher economic importance such as *Pangasianodon gigas, Probarbus jullieni*, and *Mystus nemurus*. Furthermore, tilapia seed production is no longer necessary in reservoirs where the fish has been found to reproduce naturally, e.g., Lam Takong, Ubolratana, Lam Pao, and Lampraplerng. Thus, tilapia seed produced at present is used mainly for the purpose of stocking recently built reservoirs and village ponds. Very small amounts of the seed is produced for use in research work and demonstration activities.

Table 1
Fish seed production by the DOF fisheries stations (in millions), 1967 - 1990

Year	Total	*Tilapia*	*Cyprinus*	*Puntius*
1967	11.33	1.46	4.75	0.16
1968	14.14	3.42	6.04	0.64
1969	19.35	6.04	8.30	N.A.
1970	19.94	6.60	9.10	8.71
1971	20.25	6.94	8.46	0.49
1972	20.65	8.23	8.79	0.69
1973	36.57	9.21	10.17	0.59
1974	41.71	9.15	8.61	0.66
1975	39.49	11.56	8.25	1.06
1976	34.64	11.73	8.41	2.49
1977	57.59	11.82	8.39	12.03
1978	105.01	18.36	16.81	31.55
1979	118.02	19.13	16.44	35.75
1980	104.53	18.04	16.94	32.24
1981	118.34	17.48	13.06	39.47
1982	100.05	14.14	12.24	28.18
1983	155.01	15.75	9.98	38.91
1984	132.44	15.83	10.72	46.50
1985	153.75	23.16	13.38	58.56
1986	179.77	20.33	18.56	63.13
1987	156.80	15.71	13.63	56.69
1988	142.92	17.93	16.04	53.72
1989	176.04	15.24	20.19	69.69
1990	185.76	16.56	20.73	78.66

Source: Department of Fisheries (1988a) and additional data provided by this Department.

Millions of tilapia fingerlings have been stocked into waterbodies each year since the start of the Fish Stocking Program. However, in view of the fact that fish stocking is conducted only whenever fingerlings are available, and because it happens that several thousands of fish of different sizes may be stocked into a particular reservoir many times in the past years, it is extremely difficult to attempt data analysis for the purpose of evaluating the success of the stocking program. Nonetheless, rough estimates show that about 80 per cent of the total tilapia seed produced by the fisheries stations is released each year. In 1988 and 1989, for instance, the total number of fingerlings stocked reached about 14.2 and 11.64 million, respectively (Department of Fisheries, 1988b).

4. PRODUCTION

Freshwater fisheries production in Thailand has decreased from 116,500 mt in 1981 to 81,500 mt in 1988 (Table 2). The contribution of tilapia to total freshwater fish production ranged from 300 mt in 1985 to 13,600 mt in 1984, equivalent to 0.3-12 per cent of total production, generally lower than that of *Puntius* and *Ophicephalus*, both of which are common to all reservoirs.

Table 2
Production from freshwater fisheries (in '000 t), 1981-1988

Year	Total		*Puntius*		*Ophicephalus*		*Tilapia*		Value (million baht) (only for tilapia)
1981	116.50	(48.10)	*	(4.20)	*	(8.70)	*	(5.50)	-
1982	87.80	(45.80)	*	(5.70)	*	(5.70)	*	(7.20)	-
1983	108.50	(47.00)	11.60	(5.10)	16.40	(4.80)	2.5	(12.10)	-
1984	111.40	(50.40)	15.20	(4.90)	15.50	(4.90)	13.6	(7.90)	312.40
1985	92.20	(75.30)	8.70	(7.30)	14.40	(7.40)	0.3	(15.10)	272.60
1986	98.50	(89.30)	13.00	(8.80)	17.50	(6.00)	4.9	(18.40)	279.40
1987	87.30	(89.80)	5.80	(11.10)	16.30	(3.30)	10.3	(17.00)	352.20
1988	81.50	(102.10)	8.90	(13.00)	11.80	(4.00)	8.8	(18.80)	361.30

* Not available.
( ) Production from aquaculture.
Source: Department of Fisheries (1988a) and additional data provided by this Department.

Tilapia is mainly caught in the different types of freshwater impoundments in the country where they exhibit varying degrees of performance. In 1986 and 1987, tilapia contributed 10.83 and 18.73 per cent, respectively, to the total fish catch from reservoirs in the country, the highest among six commonly caught species in such waters (Table 3). In public waters, tilapia comprised 12.94 per cent of the fish catch in 1986 and 8.35 per cent in 1987 and in village ponds, they constituted 20.68 and 13.31 per cent of total fish catch in 1986 and 1987, respectively (Table 3). In 1988, the total yield of tilapia from Thai impoundments was estimated at 5,313 mt, i.e., 2,983 mt from reservoirs, 1,870 mt from public waters, and 460 mt from village ponds (Table 4).

Table 3
Percentage production of tilapia and other major fish genera in catches in reservoirs, public waters, and village ponds, 1986-1987

Species	Reservoirs		Public Waters		Village Ponds	
	1986	1987	1986	1987	1986	1987
Oreochromis	10.83	18.73	12.94	8.35	20.68	13.31
Ophicephalus	3.06	15.22	0.12	0.04	0.12	-
Cirrhinus	10.46	3.63	7.06	4.73	1.29	6.88
Puntius	11.56	16.33	16.06	13.68	20.77	14.08
Corica	10.63	0.02	0.03	0.21	0.01	-
Labeo	1.73	4.56	2.12	1.42	2.34	3.88

* Low production may come from incomplete data collection.
Source: Department of Fisheries, 1988a.

Table 4
Fish production (mt) from reservoirs, public waters, and village ponds Thailand, 1988

Species	Reservoirs	Public Waters	Village Ponds	Total
Carp	2,492	2,755	331	5,578
Tilapia	2,983	1,870	460	5,313
Murrel	2,343	2,885	201	5,429
Other	12,825	9,528	1,186	23,539
Total	20,643	17,038	2,178	39,859

Source: Department of Fisheries, 1988a.

Large reservoirs with a surface area exceeding 1,000 ha seem to have a high potential to become major sources of tilapia in the country. The average tilapia landing from nine reservoirs in 1988 was 58 mt, ranging from 2.06 mt in Kangkrachan to 276.47 mt in Keiwlom (Table 5). Considerable amounts of the fish are observed in the catches of other large reservoirs, but landing statistics are not available. Tilapia has also been found among fish populations in some small reservoirs but tilapia landings have never been recorded (Chookajorn *et al.*, 1983).

Table 5
Fish landings from large reservoirs in Thailand, 1988

Reservoir	Surface Area (ha)	Fish Landing (mt)				
		Carp	Murrel	Nile Tilapia	Others	Total
Kangkrachan	5,000	113.25	4.13	2.06	31.42	150.86
Sirinthorn	30,400	90.15	6.62	12.12	636.84	745.73
Ubolratana	41,000	1,086.86	14.06	2.80	614.25	1,717.97
Sirikit	29,700	82.13	4.23	26.24	316.24	428.84
Chulaporn	1,250	10.21	1.89	7.93	9.03	29.06
Nampung	2,000	7.84	3.21	8.58	23.01	42.64
Lam Pao	24,000	328.47	*	100.89	2,390.39	2,819.75
Srinakarin	40,000	112.24	45.01	85.46	*	*
Keiwlom	1,600	270.39	134.50	276.47	147.89	829.25
Average		233.50	23.74	58.06		

* Not available.
Source: Department of Fisheries, 1988a.

Of the total tilapia production, a small portion also comes from pen and cage culture which has normally been practised with more commercially important species like sand goby (*Oxyeleotris marmoratus*), sea bass (*Lates calcarifer*), and grouper (*Epinephelus malabaricus*). The latter two species are normally raised in Songkhla Lake and adjacent waters. Intensive tilapia cage culture is now under experimentation at Ubolratana Reservoir, with special emphasis on cage design and rate of stocking and feeding (Ubolratana Reservoir Research Station, 1989).

5. ECONOMICS AND MARKETABILITY OF TILAPIA

It costs the fisheries stations about 10 baht to produce 100 tilapia fingerlings depending upon the size produced. The fingerlings are usually distributed at a size of 3-5 cm for aquaculture and larger for stocking. With the recent average production of 11-14 million fingerlings per year, annual cost of production of tilapia for stocking purposes may vary from 1-1.5 million baht (1US$ = 25.38 baht, 1992). When tilapia reaches marketable size, usually more than 300 g in weight, the fish is sold at about 15-20 baht/kg. With head and gut removed, the fish may cost up to 50 baht/kg in supermarkets. The average value of tilapia landed between 1983 and 1988 was computed at about 134 million baht.

6. CONCLUSION

The success of the tilapia seed production and intensive stocking programs of the Thailand Department of Fisheries has resulted in the fish now appearing in commercial catches and making significant contributions to the production of major reservoirs. Tilapia is the only introduced species that promises stocking return as it reproduces naturally in several reservoirs, thus eliminating the need for continuous stocking. The contribution of tilapia to total freshwater production is similar to that of *Puntius*, a local economically important species, with average production as high as 6,730 mt valued at over 100 million baht from 1983-1988. Production from pen and cage culture is not significant, however, due to the high investment required and the lack of appropriate locations for culture, but is now under experimentation and may just become more important in the coming years.

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TILAPIA IN CAPTURE AND CULTURE-ENHANCED FISHERIES IN LATIN AMERICA

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I. INTRODUCTION

In Latin America, the freshwater fisheries developed in parallel to aquaculture, with both apparently centered on the use of exotic species for stocking in inland waters, except in a few cases where the high diversity of endemic species has led to their development in favor of the exotics.

It is perhaps for this reason that species from other regions have been brought into the Latin American countries. Tilapia, for example, was introduced in the 1950s and since then, has established itself either as an important component of the capture fisheries, as in Brazil, or as an important culture species, as in Cuba and Mexico. In these latter two countries, tilapia contributes significantly to freshwater fisheries, with yields comprising 99 and 63 per cent of total freshwater fish production, respectively. Cost-benefit models developed in Latin America, particularly in Cuba and Mexico, have likewise confirmed the profitability of the use of tilapia in geographic regions where it has been introduced. The development of culture-enhanced fisheries, specifically in Cuba and Mexico, has led to improved diets and socio-economic conditions in the rural and suburban areas although some scope exists for further improvements in the future.

This paper offers a brief account of the impacts of tilapia introductions on the capture and culture-enhanced fisheries in Latin America. It includes information on the history and objectives of tilapia introduction and describes the current situation with respect to the tilapia fisheries in Brazil, Cuba, and Mexico where tilapia has been making significant contributions to fish production.

2. TILAPIA SPECIES INTRODUCED IN LATIN AMERICA

Hydropower reservoirs in Latin America, and particularly in Central America, have been widely used for fish production through the stocking and restocking of various fish species, mostly cyprinids and tilapia.

Since 1950, seven tilapia species have been introduced in many countries in the Region, primarily to complement the native stocks and to increase the yields from culture-enhanced fisheries and/or aquaculture. These seven species are: *Oreochromis aureus, O. mossambicus, O. niloticus, O. niloticus x O. mossambicus hybrid, O. urolepis hornorum, Tilapia rendalli,* and *T. zillii.*

The origins of these seven species vary. In most cases, the source is another Latin American country or the USA; in some, the origin is an Asian country (e.g., Philippines, Taiwan), an African country (e.g., Cote d'Ivoire, Zaire), or is unknown (Table 1).

3. CURRENT STATUS OF TILAPIA UTILIZATION IN LATIN AMERICA

3.1 Bolivia

As in other countries of the Region, the seeding of waterbodies is being undertaken in Bolivia as a tool for utilizing their production potential. This scheme was started in 1930 and in 1960, *O. niloticus* was introduced from Brazil (Zuna, 1984).

3.2 Ecuador

The tilapia hybrid (*O. niloticus* x *O. mossambicus*) was introduced in 1974 to satisfy some extension programs (Alvarez, 1984).

3.3 Guatemala

Since 1955, different species of tilapia have been introduced by Government agencies into the country's major waterbodies to support the development of culture-enhanced fisheries and provide the basis for tropical aquaculture (Martinez, 1984).

3.4 Honduras

In 1956, the first tilapia introduction (*O. mossambicus*) took place in the country's continental waters. More recently, other species were introduced, i.e., *O. niloticus* and *O. niloticus* x *O. mossambicus* hybrids in 1978 and *O. urolepis hornorum* in 1979. The El Picacho Fishfarming Station was set up to produce the fry/fingerlings for stocking in the open waters (Berrios, 1984).

Table 1
Tilapia introductions in Latin America (from Welcomme, 1988)

Species Introduced	Year of Introduction	Recipient Country	Country of Origin
Oreochromis aureus	1965	Brazil	USA
	1965	Costa Rica	El Salvador
	1968	Cuba	Mexico
	63/69	El Salvador	USA
	1974	Guatemala	El Salvador
	1964	Mexico	USA
	1978	Nicaragua	Costa Rica
	1987	Panama	Puerto Rico
	1983	Peru	Cuba
O. mossambicus	1960	Brazil	Unknown
	1960	Colombia	USA
	1960	Costa Rica	Unknown
	68/83	Cuba	Mexico
	1950	Dominican Republic	Santa Lucia
	1958	El Salvador	Guatemala
	1955	Guatemala	El Salvador
	1956	Honduras	El Salvador
	1964	Mexico	USA
	1959	Nicaragua	El Salvador
	1950	Panama	Unknown
	1981	Peru	Panama
	1958	Venezuela	Trinidad
O. niloticus	1977	Bolivia	Brazil
	71/72	Brazil	Ivory Coast
	1980	Colombia	Panama
	1979	Costa Rica	Panama
	1967	Cuba	Peru
	1979	Dominican Republic	Unknown
	(?)	Ecuador	Unknown
	1979	El Salvador	USA
	1974	Guatemala	El Salvador
	1978	Honduras	USA
	1978	Mexico	Costa Rica
	1964	Nicaragua	El Salvador
	1976	Panama	Brazil
	78/80	Peru	Brazil; Panama
O. niloticus x O. mossambicus	1979	Cuba	Philippines
	1981	Dominican Republic	Taiwan
	1978	Honduras	Panama
O. urolepis hornorum	71/72	Brazil	Ivory Coast
	(?)	Colombia	Unknown
	1960	Cuba	Mexico; Nicaragua
	1980	Dominican Republic	Panama
	1979	El Salvador	USA
	1974	Guatemala	El Salvador
	1979	Honduras	Panama
	1978	Mexico	Costa Rica
	1974	Nicaragua	El Salvador
	1976	Panama	Brazil
	78/80	Peru	Brazil; Panama
Tilapia rendalli	1953	Brazil	Zaire
	1960	Colombia	USA
	1970	Cuba	Mexico
	1979	Dominican Republic	Mexico
	1960	El Salvador	USA
	1974	Mexico	Unknown
	1977	Panama	Puerto Rico
	1966	Peru	Brazil
Tilapia zillii	1970 (?)	Mexico	USA

3.5 Nicaragua

The development of freshwater fisheries and aquaculture is still in its infancy and present efforts are directed primarily at promoting the use of tilapia and at adapting available technologies to suit local economic and environmental conditions.

Several tilapia species have been introduced into Nicaragua, starting with *O. mossambicus* in 1959 and *O. urolepis hornorum, O. aureus,* and *O. niloticus* in the 70s (INPESCA, 1980). A hatchery formerly known as the *Hacienda La Calara*, now called Omar Torrijos hatchery, was established to receive the broodstock and propagate these species. Annual production of these cichlids was three mt in 1984, one mt in 1986 (FAO, 1989), and 16 mt in 1989 (Sanchez *et al.*, 1989)

Recent reports show that seven small dams with an aggregate surface area of 2.4 ha, have been stocked with tilapia and some cyprinids are being managed by local cooperatives with financial assistance from government agencies (Sanchez *et al.*, 1989).

The fisheries productive potential of dams in Nicaragua has been estimated to be high and tilapia has been said to be the most important species in the country's continental waters. In the document, *Esquema Pesquero de la Republica de Nicaragua*, 1985 (General Scheme for the Perspective Development of the Fisheries Sector in the Republic of Nicaragua, 1985), tilapia production was projected to be 210, 456, and 1,383 mt, equivalent to 36, 26, and 28 per cent, respectively, of the total freshwater production for the three stages of the country's fisheries development (Sanchez *et al.*, 1989).

3.6 Panama

The utilization of the fishery resources in continental waters, one of the country's development strategies since 1950, remains very much a component of the present Aquaculture Program being promoted by the *Direccion Nacional de Acuicultura* (National Directorate on Aquaculture) (DINAAC, 1984).

In line with this strategy, *O. mossambicus* was introduced in 1950 and other species followed more recently (Table 1). The Divisa Experimental Station was also set up to produce the tilapia fingerlings for stocking and restocking the dams whose total surface area available for freshwater fisheries is 42,949 ha. Of this area, some 42,500 ha is attributable to Gatun Lake where the main species exploited is *Cichla ocellaris*, a predator fish (commonly known as *sargento*) from the Amajar-Orinoco system. The remaining 449 ha consist of 86 dams, lakes, and small ponds where tilapia (*O. niloticus*) is present together with guapote tiger fish (*Cichlasoma manaquense*), common carp (*Cyprinus carpio*), and other less important species (DINAAC, 1984).

In 1976, fishfarming was introduced at the Laguna de la Yeguada, a 100-ha man-made lake, where *C. ocellaris* (*sargento*) was accidentally introduced and subsequently displaced such indigenous species as *vieja* (*Cichlasoma moculicanda*), *sabalo* (*Brycon chorogrensis*), and *bocachico* (*Currimatus magdalenae*), among others. In an effort to counteract the negative influences brought about by this predator species, 200 adults of the tilapia hybrid (*O. niloticus* x *O. mossambicus*) were introduced in the lake. Two years later, 6,000 *C. carpio* fingerlings and 10,000 breeders of *Hypophthalmichthys molitrix* were introduced (Vazques de S. *et al.*, 1988). These introductions, particularly tilapia, turned out to be successful and have become the basis of a fishery that now benefits some 715 families belonging to 20 communities.

The experience at Laguna de la Yeguada has also been replicated at Gatun and Alajuela lakes where a program on artisanal fisheries has been formulated with the following objectives:

(i) To supply the high-protein, low-cost food requirement of the local populations;

(ii) To promote artisanal fishing as a primary economic activity in lieu of livestock production and crop agriculture and thus, generate permanent jobs in the rural areas;

(iii) To organize fishing cooperatives that will assist the local fishermen in fishing and in other productive activities that would enable them to improve their socio-economic conditions; and

(iv) To eventually restore the lake ecosystem to its condition prior to the introduction of *C. ocellaris* by increasing the fishing effort on populations of this predatory species.

Since the start of the Program, two fishing groups have been organized and have started experiments to determine the appropriate fishing methods, mesh sizes, and fishing effort. At Gatun lake, three fishermen's groups have been organized and about 45 families are supported by the lake's fishery. Annual production has been estimated to be 45-50 mt, with each fisherman going fishing only two days a week.

3.7 Paraguay

Aquaculture is mainly undertaken in small farms for subsistence purposes. Its development started in 1964, with ponds ranging in size from 200 to 360 sq m built for the culture of *O. niloticus*, *T. rendalli*, and *O. aureus* (Anon., 1988). Records show that development was limited by the heavy dependence on external funding support so much so that in 1982, only six out of the 565 ponds registered in 1977 were operating - three for tilapia culture and three for carp culture. (In 1977, a production of 22 mt was recorded from the 565 tilapia and carp ponds). Support for aquaculture activities has since increased and about 1,200 ponds have been producing again although still at the subsistence level. Production is now estimated at around 54 mt/yr.

3.8 Peru

This country's experience in the field of inland fisheries and aquaculture started 50 years ago. Nevertheless, it seems that no important impact has been registered in terms of product supply; in the last 10 years, there has been a slow and disorderly expansion of activities mainly focused towards satisfying domestic demand (CEIDAP, 1989).

The first introduction of tilapia was registered in 1966 when *T. rendalli* was imported from Brazil (Vera, 1984). Years later, *O. niloticus, O. urolepis hornorum, O. mossambicus,* and *O. aureus* were introduced to develop fishfarming in the Amazon region.

Actions aimed at repopulating dams and open waters have been carried out in some Amazon dams (e.g., Lake Sauce in San Martin Department), and at the coast (e.g., San Lorenzo dam), mainly using *T. rendalli*. No information is available, however, on the general behavior and average yields from their fisheries. Fingerlings are produced by some hatcheries established by the Government, mainly the Ahuashiyacu hatchery at the San Martin Department.

4. CASE STUDY OF TILAPIA PRODUCTION: CUBA

4.1 General Information

The Republic of Cuba is largely represented by the major island which covers 110,922 sq km and is the biggest island in the Antilles; the others are the Juventud Island (2,200 sq km) and other small and medium islands around it. Cuba Island is 1,250 km long and has a maximum width of 191 km and a minimum of 31 km.

Only one-quarter of the Cuban territory is mountainous. The three main systems are: (i) the Guaniguanico chain of mountains in the west, with a height of 750 m; (ii) the Trinidad-Sancti Spiritus chain of mountains in the center with a height of 1,100 m; and (iii) the Sierra Maestra in the east with mountains higher than 1,700 m above sea level. The rest of the territory is flat and very fertile and is used for the production of sugar cane, tobacco, and other agricultural products.

Most of Cuba's 202 rivers are short, the longest being El Cauto (370 km) followed by Zaza (155 km), Sagua La Grande (163 km), Agabama (105 km), and other shorter ones.

The natural lakes are very small. For a long time, the Laguna de Ariguanabo was considered the biggest in the country; however, the level of this lake has been reduced because of the use of its water to supply industries and cities. Another important lake is the circular Tesoro de la Cienega de Zapata with a surface area of nine sq km and a minimum depth of 10 m. The most important lacustrine region is

located in the west side of the island at the Guanhacabibes isthmus, where there are more than 100 lakes between coasts, the biggest one (Laguna del Pesquero) with a surface area of four sq km.

The most important activity is agriculture and the most important product is sugarcane. The fisheries industry has grown from 21,900 mt in 1958 to more than 200,000 mt in 1985 (Anon., 1985). The industry has also diversified into international waters of the North Atlantic, Southern Africa, and other regions of the Pacific Ocean. On the other hand, the construction of dams during the last 25 years has made it possible to develop an important aquaculture industry based on the use of reservoirs.

4.2 The Inland Fisheries

The Cuban aborigines were said to consider fishing more important as compared with other types of production. Some historians from the time of the Island's discovery described ponds closed with nets with great quantities of mullets that were used to feed the native populations (Diaz *et al.*, 1989).

Fish introductions and stocking of inland waters was initiated quite recently. In 1960, the *Centro de Repoblacion Fluvial* was established to work on species adaptation and dispersal in inland waters.

During the 1970s, technical personnel were trained to handle a program intended to use water reservoirs in different regions of the country for aquaculture or culture-enhanced fisheries. At the same time, the first provincial aquaculture firms were established, which had the appropriate infrastructure to start fisheries development. By the end of that decade, the country's first fishfarming station was built under an integrated technological project, and two other projects were started.

In 1990, the *Empresa Nacional de Acuicultura* (ENACUI) (National Aquaculture Firm) was created and all provincial firms and new units were placed under it, thus establishing a nationwide network in charge of the study, development, and use of fishery resources in all inland waters. This organization got scientific personnel, aquaculture specialists and technicians, and fishermen working together towards the intensification of fish capture and the use of aquaculture in dams.

4.2.1 The Legal Framework

Fisheries is ruled by the *Ley de proteccion del medio ambiente y del uso racional de los recursos naturales*, (Law on environmental protection and the national utilization of natural resources), which provides that "...the exploitation and optimum use of fishery resources in rivers, dams, and lakes, as well as fish stocking or restocking of water reservoirs and other aquatic species, are responsibilities of the corresponding state organization according to the fisheries development plans and in line with norms approved by the Ministries Council...". Accordingly, all fisheries based on aquaculture and the use of water reservoirs should be practised and governed by a state firm.

4.2.2 Fingerling Production

Fingerling production is an activity undertaken by 12 hatcheries located all around the Island. Since 1980, fingerling production has increased significantly from three million to 33.1 million individuals in 1988 (Table 2).

Table 2
Fingerling production during the 1979–1988 period (from Mari, 1989)

Year	Fingerling production (in millions)
1979	9.3
1980	3.0
1981	5.4
1982	6.4
1983	9.0
1984	17.0
1985	20.0
1986	18.6
1987	26.4
1988	33.1

One of the first measures intended to lead towards the establishment of a culture-enhanced fisheries in the country's inland waters, was the seeding of tilapia fingerlings in dams at a density of 600 individuals/ha on a yearly basis until a commercial fishery was established. This usually developed 18 months after the seeding operations, depending on the characteristics of each dam. In dams affected by a reduction in water level, restocking had to be carried out to compensate for the negative impacts of such affected water level reduction on natural spawning. For example, it was reported that the spawner population of *O. aureus* has been adversely affected by the drastic reduction in spawning area, which is turn necessitated the reintroduction of tilapia fingerlings to replace losses from natural spawning (Mari, 1989).

4.2.3 Fishing Gear and Craft

Gill nets are the only fishing gears used in Cuban dams. The most common net used is the nylon monofilament with a mesh size of 80-160 mm. They are fabricated at a central shop run by ENACUI.

The fishing boats are made of plastic and are of two types: main boats (or *cherneras*) and auxiliary boats (Table 3). The *cherneras* are used to transport fishermen and equipment to the fishing areas with the auxiliary boats in tow. The latter are used to store the fishing gear and the catch.

Table 3
Characteristics of fishing boats

Parameter	Boat	
	Main	Auxiliary
Length (m)	5.05	4.0
Width (m)	1.78	1.4
Depth (m)	0.90	0.46
Draft (m)	0.30	0.16
Speed (mph)	2.50	-
Engine model	Yanmar	-
RPM	2400	-
Power (Hp)	12	-

Gill nets are used either passively or semi-actively; they cannot be used as active gear because of the conditions at the bottom (e.g., submerged trees and other obstacles). If it is possible for the fisherman to locate a school of fish, he uses the gillnet as a semi-active gear; otherwise, he leaves the gillnet for a few hours in an area where, based on his experience, the fish are likely to pass. This is usually practised in shallow areas close to shore with one end tied to a post on the shore and several nets tied to one another and with the extreme end tied to a weight or an anchor.

The use of gill nets as a semi-active gear involves the use of two boats with outboard engines. The boats keep on moving until a school of fish is sighted. As the boats approach the school, the motors are turned off and the boats lay their nets in a big circle, hitting the water with the oars to drive the fish into the net.

The fishermen are grouped in brigades of varying composition. In big dams, a brigade can be composed of four to six fishermen with one main boat and two or three auxiliary boats. The number of nets per fisherman and the mesh size of the net depend on findings of systematic biological and fisheries studies carried out in the dams.

4.2.4 Endemic and Introduced Ichthyofauna

The freshwater ichthyofauna of Cuba belong to the following 12 families (Alayo, 1965):

(i) *Lepisosteidae*
(ii) *Anguillidae*
(iii) *Signathidae*
(iv) *Cyprinodontidae*
(v) *Poecilidae*
(vi) *Atherinidae*
(vii) *Gobiidae*
(viii) *Synbranchidae*
(ix) *Cichlidae*
(x) *Brotulidae*
(xi) *Elotridae*
(xii) *Gobiesocidae*

After the construction of the dams, a study was conducted to determine the possible commercial utilization of the endemic species. This specific study concluded that none of the endemic species had the characteristics needed to support a commercial fishery. For this reason, exotic species were introduced in the dams to guarantee a commercial fishery. Of the introduced species, the tilapias have become the most important resource in Cuban dams.

4.2.5 Production from Culture-Enhanced Fisheries

The tilapia *O. aureus* is the most important species caught in Cuban reservoirs followed by *T. rendalli*, common carp (*C. carpio*), black bass (*Micropterus salmoides*), and other cyprinids. The tilapias have so easily adopted to the conditions in the dams that all it took for a commercial fisheries to develop is 18 months from seeding.

Over the 10-year period 1979-1988, the production from culture-enhanced fisheries increased from 4.4 mt in 1979 to 14.9 mt in 1988, with an average absolute increase of 15.9 per cent per year (Table 4; Fig. 1). Between 1984 and 1988, cichlid production from the country's 15 biggest dams accounted for an average of about 50 per cent of the total fish production from these dams (Table 5), whose aggregate surface area of 53,808 ha represents 26.7 per cent of the total reservoir area (200,000 ha) in the country.

Table 4
Fish production from culture-enhanced fisheries, 1979-1988

Year	Fish production ('000 mt)	Increase	
		Absolute	Percentage
1979	4.4	-	-
1980	6.9	2.5	56.8
1981	9.8	2.0	28.9
1982	11.8	2.9	32.6
1983	12.9	1.1	9.3
1984	14.6	1.7	13.2
1985	15.4	0.8	5.4
1986	15.6	0.2	1.2
1987	16.4	0.8	5.1
1988	14.9	-1.5	-9.1
Total	121.8	$\bar{x}$ = 1.2	$\tilde{x}$ = 15.9

The impressive performance of tilapia is attributed to the systematic fingerling stocking program coupled with increased efficiency of fishing techniques and the successful implementation of fisheries management measures, as will be discussed in Section 4.2.6. below. On the other hand, catches of the most important endemic species *biajaca* (*Cichlasoma sp.*) have slowly diminished since 1975 when 450 mt were recorded (Diaz *et al.*, 1988).

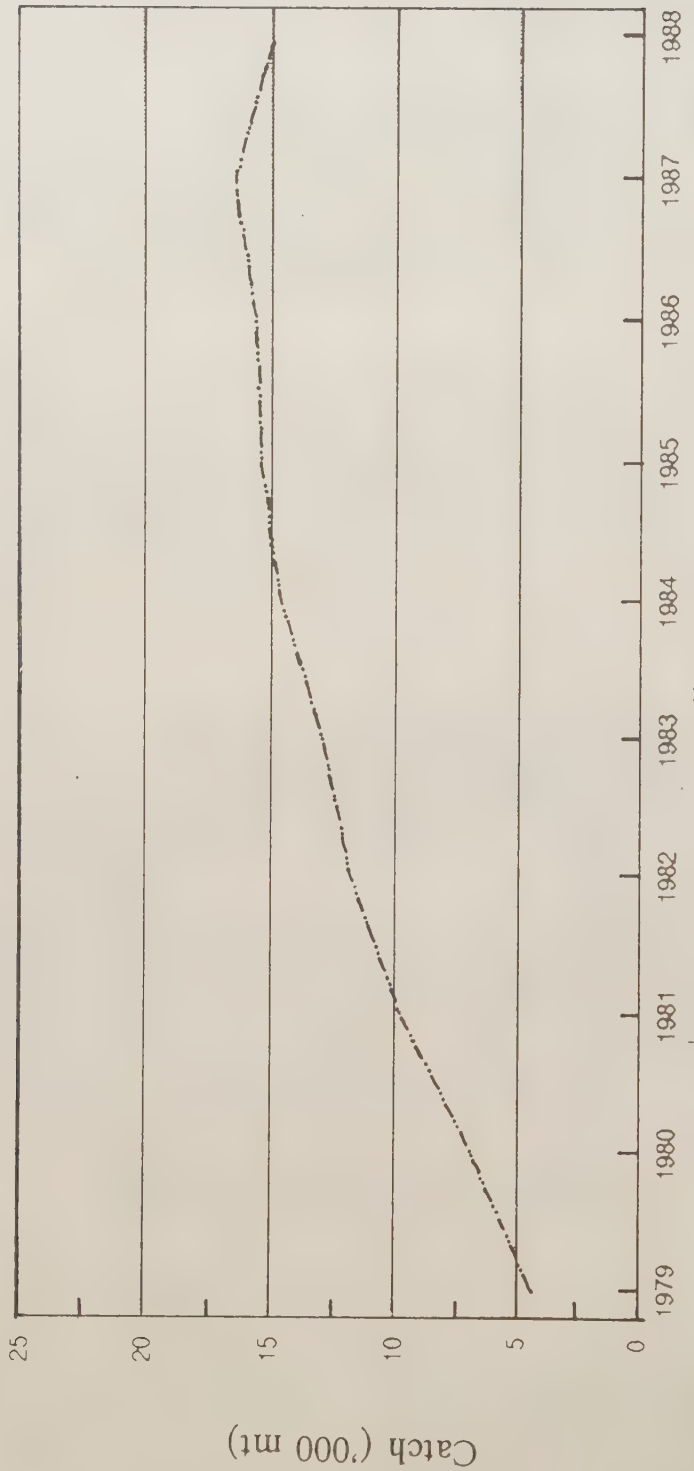

Fig. 1. Increase in production from culture-enhanced fisheries in Cuban reservoirs.

Table 5

Production (mt) and yield (kg/ha) of cichlids in the 15 largest reservoirs in Cuba, 1984–1988

No.	Description of Dam				Production (mt)					
	Name	Height, MSNM	Surface area (ha)	Kind and uses	1984	1985	1986	1987	1988	Average yield (kg/ha)
1.	Zaza	39.0	11,400	Dam, R/D/C	1,128	715	1,118	1,234	1,249	95.5
2.	Alacranes	32.5	7,620	Dam, R/D/C	2,258	2,393	1,800	1,328	196	217.1
3.	Leonero	53.7	6,600	Dam, R/C	1,013	1,790	1,917	1,664	987	223.3
4.	Porvenir	1.7	4,110	Dam, R/C	383	290	262	293	88	64.0
5.	Jimaguayu	67.7	3,520	Dam, R/C	1,276	889	895	356	748	236.5
6.	Baragua	97.0	3,240	Dam, R/C	249	127	211	304	351	76.6
7.	Munoz	34.0	2,971	Dam, R/D	383	486	377	339	461	137.7
8.	Aviles	77.0	2,440	Dam, R/D/C	739	208	220	207	198	128.8
9.	El Punto	21.0	1,890	Dam, R/C	34	22	32	56	88	24.5
10.	Cuyaguatej	5.5	1,754	C. Hidr, R/C	28	14	17	25	17	11.5
11.	Nipe	31.0	1,750	Dam, R/C	466	314	202	119	122	139.7
12.	Maximo	50.0	1,713	Dam, R/C	91	148	133	153	89	71.6
13.	Minerva	82.0	1,650	Dam, R/C	332	142	421	593	523	243.7
14.	Mamposton	137.8	1,620	Dam, R/C	67	56	124	83	70	49.3
15.	Najasa	83.0	1,530	Dam, R/C	14	628	583	742	307	297.2
	Total		53,808		7,861	8,641	8,312	7,496	7,494	
	% of national production				54	56	53	46	37	

Legend: R = irrigation
C = flood control
D = sport fishing

4.2.6 Fisheries Management in Reservoirs

Reservoirs are managed for fisheries through the implementation of regulatory measures like setting capture limits, closed seasons, closed areas, and mesh size restrictions.

(i) Capture Limits

In reservoirs used for commercial production, an annual capture limit is established using any of the following:

- Morphoedaphic index equation (MEI);
- Historical capture series and efforts analysis;
- Equation relating the capture per area unit against phytoplankton; and
- Application of predictive models.

The evaluation is supported by results of systematic fisheries sampling and biological studies (such as growth, fecundity, gonadal condition, and first maturation size) which enable the determination of the general condition of the fish population and its level of utilization.

(ii) Closed Seasons

In Cuban reservoirs, closed seasons are imposed to protect specific life stages of commercially exploited fish species. For example, fishing is not allowed during the peak of the spawning season of *O. aureus* which lasts from February to August. It is difficult for the fishermen to abide by this regulation especially because fish catches increase during that season. Nevertheless, they cooperate after they are convinced that there is a need for closed seasons as a means of controlling fishing effort and ensuring the sustainability of the resource.

(iii) Closed Fishing Areas

Another method to reduce fishing effort in Cuban reservoirs is the establishment of closed areas for fishing. In the case of big and medium dams, this area is established based on previous knowledge on the species' life cycle. These are generally well known for all species that are used for commercial fishing in Cuban reservoirs, particularly *O. aureus*.

(iv) Mesh Size

Mesh size regulations are based on the results of previous sampling which give information on sizes, weights, and sex proportion, among others. In addition, the individual weight for tilapia has to be greater than 230 g (Diaz, 1989). On the basis of length-weight equations previously established for the main reservoirs, the estimated weight of tilapia in each one of them is known. These, together with the results of selectivity studies made using different mesh sizes, allow the establishment of proper measures for fisheries management.

(v) Predictive Modelling

Yields from culture-enhanced fisheries in Cuban reservoirs have been estimated based on various hydrobiological parameters. The maximum sustainable yield (MSY) of the fisheries in certain reservoirs has been estimated as basis for the imposition of regulatory management measures. Two case studies are relevant in this regard: the Maximo Reservoir model and the Mamposton Reservoir model.

* The Maximo Reservoir Model

Maximo Reservoir, an irrigation and flood control reservoir with a surface area of 1,713 ha, was classified as a mesotrophic reservoir in 1988 (Mari, 1989). Studies conducted in 1988 on its water quality, hydrobiology, and primary productivity revealed the following: low nutrient concentration; importance of algae, other periphyton, and macrophytes such as *Elodea canadensis* and *Nitella sp.*; low zooplankton diversity; and *O. aureus* feeding on phyto-, peri-, and zooplankton.

The low nutrient concentration in the water was attributed by Mari (1989) to the abundance of aquatic macrophytes which in turn forces the tilapia to feed on periphyton and zooplankton. On the other hand, the reduction in water surface of the reservoirs in 1986 and 1987 affected its shallow areas which in turn affected the reproduction of *O. aureus*.

Using catch and effort statistics for the period 1982-1989, the state of the fishery was evaluated using the predictive models developed by Schaefer (1954) and Fox (1970). The results of this predictive modelling indicate that from 1985-1987, production levels were above the theoretical equilibrium values (Table 6).

Table 6
Predictive catch and effort parameters for the Maximo reservoir model

Model	Maximum sustainable yield (kg)	Effort (MDF)	CPUE (kg/FDP)
Fox	125	2,703	46
Schaefer	133	2,228	60

CPUE = Catch per unit effort
MDF = man-days fishing
FDP = Fishing days per person

From the analysis of the monthly historical data on the optimal number of man-days fishing (MDF) and assuming one month of closed season (April), the distribution of efforts was programmed as follows:

Month	J	F	M	A	M	J	J	A	S	O	N	D
Effort (MDF)	234	219	335	-	224	203	241	216	232	241	292	151

This distribution was based on the following assumptions: 20 days fishing and 10 days resting and a daily average of 12 fishermen for a total of 2,588 man-days fishing. Using these parameters, fishing in 1989 was limited to 129 mt and the following fishing team compositions and fishing net mesh sizes: two, 100 mm; four, 120 mm; and two, 140 mm. In addition, considering water level fluctuations in the reservoir, shore cleaning was regularly undertaken to keep it free for fishing activities.

All these measures allowed the exploitation of only a part of the fish population without affecting recruitment in the coming years.

* **The Mamposton Reservoir Model**

This 1,630-ha reservoir is the biggest in La Havana province. In 1988, a biological and fishery-limnological study was conducted to evaluate the reasons behind its low fish production. Using catch and effort historical series for the 1982-1988 period, the fisheries were evaluated using Schaefer's predictive model (1954).

The hydrobiological studies showed that phytoplankton concentration in this reservoir was typical of a mesotrophic reservoir, with concentrations of 2.9 and 1.6 million cells per liter during the rainy and dry seasons, respectively. The mean zooplankton abundance was between 73,000 and 250,000/cu m in 1987; the density of benthic organisms was reported to be 1,000/m^2. Analysis of catch and effort statistics using Schaefer's model revealed that fish catch in 1986 exceeded the maximum sustainable yield (MSY).

Based on the studies made, the distribution of effort was planned, establishing a total closed season in the month of May and using 20 days fishing and 10 days resting every month except May, according to the following table:

Month	J	F	M	A	M	J	J	A	S	O	N	D
Effort (MDF)	122	142	157	178	-	178	173	192	137	152	117	118

Using this information, the program for *O. aureus* fishing operation in 1989 was aimed at reducing catch levels down to MSY and keeping CPUE at an average of 62 kg/MDF. It was estimated that if these targets are reached, a catch of 104 mt could be attained at an effort level of 1,666 MDF.

(vi) Conclusion

These models illustrate the system used by the Cuban authorities in managing their culture-enhanced fisheries. Their applicability may be limited, however, by certain factors such as parasitism and the presence of predators, which somehow affect the production potential of the reservoirs. The incidence of parasitism in Cuban reservoirs is high during the dry season, particularly for different trematode species. Because of this, Cuban authorities suggest that seeding or restocking activities be carried out in the

rainy season so that risks from parasitism are reduced. High populations of fish-eating birds and predatory fish have also been recorded in Cuban reservoirs. In the first case, no control measures are taken because of the complexity of the problem. In the case of predatory fishes, such as largemouth black bass (*Macropterus salmoides*) that prey on the tilapias, their control is promoted through intensive fishing using nets with the proper mesh size.

5. CASE STUDY: BRAZIL

5.1 General Information

The Federal Republic of Brazil, situated in South America, has a land area of 8,511,965 sq km. Brazil is not a mountainous country; only three per cent of its area is situated at an altitude of more than 900 m above sea level and its highest mountain does not reach 4,000 m.

There are six regions with well-differentiated geographic and climatic characteristics: the north or Amazonic region which is low, flat, humid and warm, with large rivers and dense tropical rain forests; the middle north region; the northeast region, which is semi-desert and with longlasting drought seasons; the east, with fertile soils, broken grounds, and a humid climate in the shores; the south, with moderate climate and with high agricultural livestock and industrial production; and the central west.

Brazil's fluvial system is one of the largest in the world (44,000 navigable km) and with a high hydroelectric potential. The main river basins are the Amazonas in the North, the Rio de la Plata in the South, and several other rivers which discharge directly into the Atlantic.

It is estimated that there are 68,000 dams and reservoirs in the country with a total flooded area of 5.32 million ha. The northeast region has the highest number (about 60,000), followed by the southeast, south, west-center, and north. With respect to the flooded area, the southeast region has the highest potential with its 2.6 million ha.

More than the 70 per cent of the total number of reservoirs (about 50,000) constitutes a group with individual areas larger than 10,000 ha and whose aggregate flooded area is 2.88 million ha.

5.2 Culture-Enhanced Fisheries in Inland Waters of Northeast Brazil

5.2.1 Overview

Fisheries activities started in 1948 in 104 reservoirs with an area of 182,495 ha. Over the period 1979-1989, average production from these waters reached 17,088 mt/yr, equivalent to 8.1 per cent of the total freshwater fish production of the country. The catches are dominated by tilapia (*O. niloticus*).

Fishing is practised by 4,258 fishermen/month, on the average. There are some 7,025 boats, of which 6,864 are non-powered and 161 are powered. The most common fishing gear are the gillnet and the longline. Fishing effort was four mt/yr/fisherman, corresponding to a production of 10.9 kg/day.

5.2.2 Fish Species

Over a 50-year period, some 40 fish species and two crustacean species were introduced into Northeast Brazil from other regions of the country as well as from abroad (see Table 7 for the most important species). Of these introduced species, fifteen form an important part of the catches.

Table 7
Major introduced fish/crustacean species that occur in the catches in Northeast Brazil and their origins

Common Name	Scientific Name	Origin
Acara zebu	*Geophagus surinamensis*	native
Acara comun	*Cichlasoma bimaculatum*	native
Apaiari	*Astronotus ocellatus*	Amazon river
Beiru	*Curimatus cibiatus*	native
Camaron canela	*Macrobrachium amazonicum*	Amazon river
Bagre blanco	*Selenapsis herzbergi*	native
Cangati	*Trachycoristes galeatus*	native
Curimata comun	*Prochilodus cearensis*	native
Curimata pacu	*P. argenteus*	S. Fco river
Carpa comun	*Cyprinus carpio*	China
Pescada cacunda	*Plagioscion surinamensis*	Amazon river
Pescada do Piaui	*P. squamosissimus*	Paranaiba river
Piau comun	*Leporinus friederici*	native
Piau verdadero	*L. elongatus*	S. Fco river
Piau de vara	*Schizodon dissimilis*	Paranaiba river
Pirambeba	*Serrasalmus rhomberus*	native
Piranha	*S. nattereri*	native
Pirarucu	*Arapaima gigas*	Amazon river
Pirapitinga	*Colossoma brachypomum*	Amazon river
Tambaqui	*C. macropomum*	Amazon river
Mucum	*Synbranchus marmoratus*	native
Tilapia do Congo	*Tilapia rendali*	Africa
Tilapia do Nilo	*Oreochromis niloticus*	Africa
Tucunare comun	*Cichla ocellaris*	Amazon river
Tucunare Pinima	*C. temensis*	Amazon river
Traira	*Hoplias malabaricus*	native
Sardinha	*Triportheus angulatus*	native

The better performance of the introduced species as compared to the native species may be attributed to the carnivorous habits and small sizes of the indigenous species. Among the exotics, tilapia, particularly *O. niloticus* introduced from the Cote d'Ivoire in 1971 (Guigol, 1984), stands out as the most important species in terms of production (Table 8).

Table 8
Contribution of exotic and native species to total production, 1980–1988

Year	Exotic species		Native species		Dominant species
	mt	%	mt	%	
1980	14,741.2	81.1	3,341.1	18.9	1, 2, 3
1981	14,966.0	78.5	4,109.9	21.5	1, 2, 4
1982	14,001.4	79.3	3,654.2	20.7	1, 2, 4
1983	11,568.4	78.7	3,132.7	21.3	1, 2, 4
1984	13,107.1	76.1	4,125.1	23.9	1, 2, 3
1985	13,409.7	77.0	4,005.1	23.0	1, 2, 4
1986	14,096.2	77.0	4,212.4	23.0	1, 2, 4
1987	11,903.0	75.2	3,932.3	24.8	1, 2, 5
1988	11,830.1	76.8	3,573.7	23.2	1, 2, 4

Legend: 1 = *Oreochromis niloticus*
2 = *Plagioscion squamosissimus*
3 = *Macrobrachium amazonicum*
4 = *Cichla ocellaris*
5 = *Hoplias malabaricus*

5.2.3 Fingerling Production

The introduced species are bred in local hatcheries (pisciculture stations). In the past eight years, these stations made it possible for a total of 50 million fingerlings to be stocked in 13,000 reservoirs and dams (Table 9). The establishment of the fisheries stations was prompted by a decree issued in 1977 mandating the protection of aquatic resources affected by the construction of dams across rivers (Studart, 1989). Sila (1989) reported the existence of 22 fish hatcheries with an estimated capacity of 112 million fingerlings/yr, of which tilapia constitutes more than 50 per cent.

Table 9
Number of fingerlings stocked in reservoirs, 1980–1988

Year	Number of Reservoirs	Number of fingerlings stocked
1980	1,720	3,376,800
1981	1,410	3,978,262
1982	1,332	4,429,842
1983	525	3,005,378
1984	3,143	4,737,532
1985	2,176	4,485,208
1986	823	4,476,120
1987	1,025	6,264,629
1988	1,480	15,217,149
Total	13,634	49,970,920

5.2.4 Management of Culture-Enhanced Fisheries

The systematic management of the country's inland waters started in the Brazilian northeast in 1947 with the creation of the *Departamento Nacional de Obras contra as Secas* (DNOCS). At present, the DNOCS administers 104 reservoirs for which it keeps statistical records on fishermen, fishing, and sailing permits, rentals, and catches. It also manages the physical infrastructure (*garita de pesca*), equipment (boats and engines), personnel, and fiscal activities at each dam. Statistics on production, fishing gear used, boats, and others are collected through surveys among fishermen or sampling in selected areas.

Management measures are implemented to increase the productivity of reservoirs in northeast Brazil. Among these measures is the eradication of carnivorous species like *piranha* (*Serrasalmus rhombeus*), *pirambeba* (*S. natereri*), and other less important ones in about 80,000 sq km of hydrological basin. Eradication has been carried out mainly using chemicals. Increased intensity of fishing for the predatory species has reduced their numbers (Studart, 1989).

Another measure taken to diminish the negative ecological impacts of dam on migratory fish was the construction of fish ladders. In the northeast region, 23 such structures have been built; in Brazil, there are 35 fish ladders at present.

5.2.5 Fishermen's organizations

The organization of reservoir fishermen into "colonies" started in this Region in 1976. Twelve years later, the number of organizations has remained just about the same, i.e., 12 colonies, with 8,000 registered fishermen operating in about 100 reservoirs.

The benefits arising from membership in such organizations include access to bank credit and to schools and medical services. Recently, some ice plants were set up for the use of the members. Their objectives have not been fully attained, however, perhaps due, in part, to their lack of full autonomy, as is the case in most rural organizations established by Government.

5.2.6 Socio-Economic Aspects

Fish from reservoirs have a wide acceptance among the rural populations because of their affordability. In this Region where there is little other animal protein available, about 60 per cent of the fish harvest is consumed locally. The *per capita* fish consumption of around five to six kg/yr is still relatively low, because of the lack of fish processing and cold storage facilities. The absence of a road network around the reservoirs limits the distribution of fish to areas close to the reservoir. These constraints effectively limit the economic potential of fisheries because value addition is rendered practically nil.

While that is the case, however, there are also indications that reservoir fisheries can yield good economic returns. For example, Fontenele (1969) reported that the investments made in some reservoirs were recovered exclusively through the proceeds from the marketing of fish caught in them. He showed that the investment in the Sarasate reservoir was recovered through commercial fishery activities during the first nine years of operation (Fontenele, 1968).

Reservoir fishermen have an average monthly income of US$165, which is about 2.5 times the minimum monthly wage in the country. This explains the growing membership in fishermen's organizations, the increasing dependence of families on fishery activities, and the degree of importance given to fisheries in this Region and as well as in the rest of the country.

6. CASE STUDY: MEXICO

6.1 General Information

Mexico, with an area of 1,958,201 square km of land, is located between the southern region of North America and the northern region of Central America. Is is an agricultural country with a strong industrial and a large service sector. It is also an important producer of raw materials, mainly petroleum. It has a population desity of 42.45 inhabitants per sq km. Since 1917, the country has been organized as a federal representative republic divided in 31 states and a federal district. Around 85 per cent of the country (except the Yucatan Peninsula and the eastern and northwestern coastal plains) is mountainous, with the major mountain ranges being Sierra Madre Occidental (1,250 km), which runs through the Pacific coast, and the Sierra Madre Oriental (1,350 km), which runs from eastern Texas to Oaxaca. Other mountain chains across the country give it its characteristic topography.

Geographic and climatic diversity promotes the integration of the physiographic regions, where water availability is directly related to precipitation. Thus, the southern region of the country, where a humid tropical climate prevails, has large rivers on which a number of hydroelectric dams were constructed.

The central and northern regions, with a subtropical dry climate, have a water deficit but several large natural lakes and a number of reservoirs are situated there.

The more important river systems belong to the following rivers: Lerma and Balsas entering the Pacific; and San Fernando, Panuco, Papaloapan, Grijalva, and Usumacinta, which enter the Atlantic ocean.

An inventory of fresh waters with potential for aquaculture, initiated in 1972, has not yet been completed. Olmos (1990) reported that in 1989 there were 700 lakes in Mexico (615 man-made and 85 natural) with a surface area of 988,008 ha. Other estimates put the area of dammed waters at 1.2 million ha (Juarez *et al.*, 1984). Some 24 of the dams listed each exceed 10,000 ha in area and collectively account for 70 per cent of the total lake and reservoir surface area.

6.2 Culture-Enhanced Fisheries in Inland Waters

6.2.1 Background

The size of the country as well as its geographic and climatic diversity, have favored the development of culture-enhanced fisheries. This, in turn, has led to the improvement of the socio-economic status of the people residing around the lakes and reservoirs and where fisheries have become an important and a profitable activity.

The use of lakes for fisheries, particularly the large ones (e.g., Chapala, Cuitzeo, and Patzcuaro), dates back to the times of the Spanish conquest. In contrast, reservoirs are of recent origin, having been constructed only since the 1950s. Between 1950 and 1970, the public sector agencies in charge of fisheries and aquaculture development, concentrated their efforts on seeding and restocking of dams with fishery potential. After 1970, the stocking of tilapia and carp intensified, necessitating the establishment of several fishfarming stations and new importations of species introduced earlier. For many years, aquaculture development was evaluated based on the quantity of fingerlings produced at the fishfarming stations (Cabrera *et al.*, 1984).

6.2.2 Legal Framework

The exploitation of the fisheries resources in inland waters is governed by the *Ley Federal de Pesca* which was updated in 1989. Under this law, fisheries in natural lakes and reservoirs is considered part of aquaculture.

6.2.3 Production Performance

The culture-enhanced fisheries in reservoirs in Mexico have reached a high level of development, primarily as a result of the success of the stocking program in recent years. These fisheries in the major reservoirs have been making increasingly greater contributions to the total annual fish production - from 43,507 mt (equivalent to 32 per cent) in 1982 to 123,000 mt, representing 65.1 per cent of the total freshwater fish production in 1989 (Table 10; Figs. 2 and 3).

Table 10
Contribution of the culture–enhanced fisheries in the major reservoirs and lakes to total annual freshwater fish production (from SEPESCA, 1990)

Year	Annual freshwater fish production (mt)	Production from reservoirs and lakes	
		(mt)	% of annual freshwater fish production
1980	85,751	nd	nd
1981	129,533	nd	nd
1982	135,926	43,507	32.0
1983	122,148	78,942	64.6
1984	144,034	92,789	64.4
1985	133,309	83,956	62.9
1986	151,124	101,859	67.4
1987	174,385	117,107	67.1
1988	184,339	120,385	65.3
1989	188,785	123,000	65.1

nd = no data

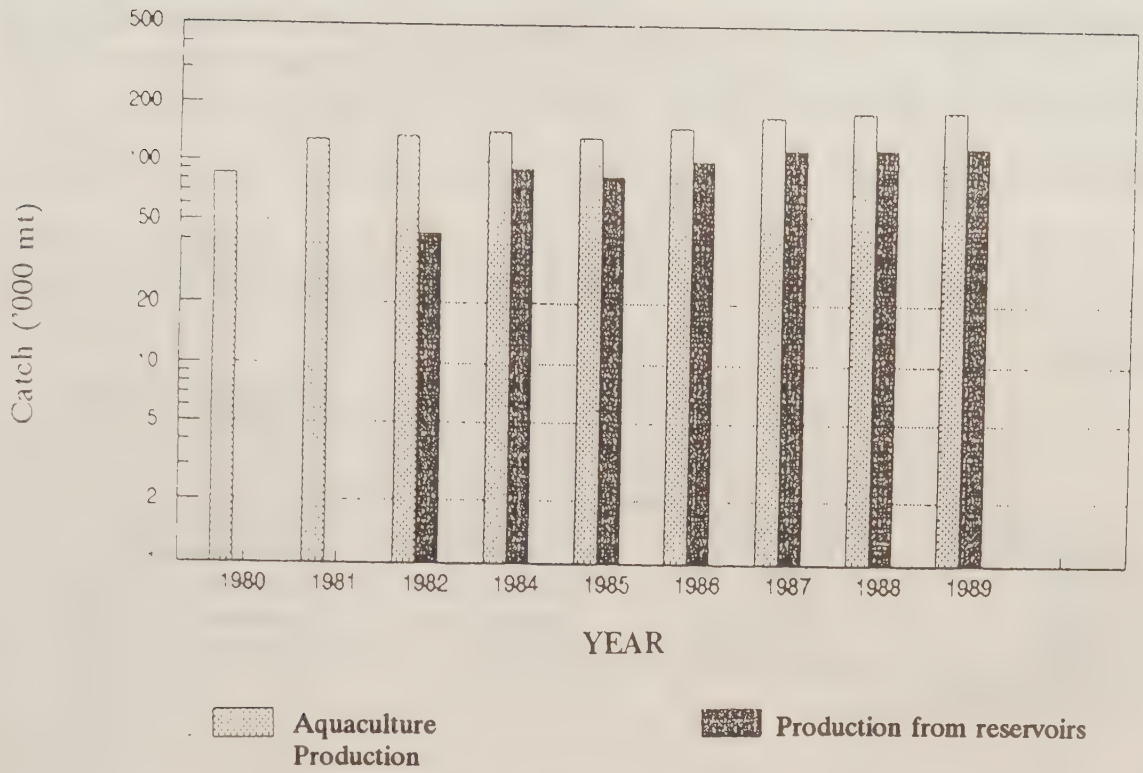

Fig. 2. Contribution of culture-enhanced fisheries to total annual production from freshwater fisheries.

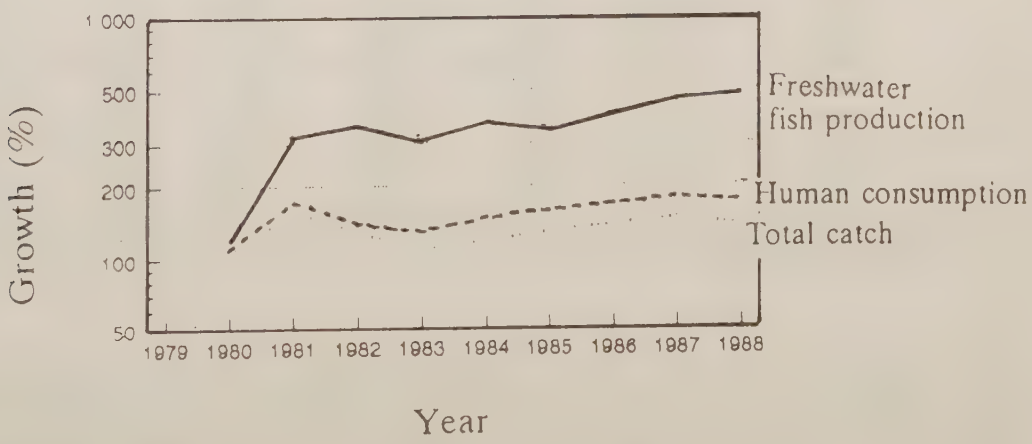

Fig. 3. Comparative growth rates of freshwater fish production, total catch, and human consumption.

Reservoir fisheries activities are administered by the *Secretaria de Pesca* (SEPESCA) which has the organization that allows it to have representatives in every state. The setting up, inspection, and registry of statistical files are dealt with by the *Oficinas de Pesca* which have offices in cities close to the large reservoirs.

6.2.4 Fish Species

There are more than 500 fish species in the inland waters of Mexico. Only 60 appear in the commercial catches, of which the three most important are all tilapias (Table 11). In the past 10 years, tilapia, mainly *O. aureus*, has dominated the catches (Table 12).

Table 11
Most important fish species caught in Mexican lakes and reservoirs.

Common name	Scientific name	Common name	Scientific name
1. Tilapia	*O. aureus* *	5. Charal	*Chirostoma spp.*
2. Tilapia	*O. niloticus* *	6. Bagre	*Icatlurus spp.*
3. Tilapia	*O. mossambicus* *	7. Pescado blanco	*Ch. estor estor*
4. Carpa	*Cyprinus carpio* *	8. Lobina	*M. salmoides*

* Introduced species

Table 12
Production (mt) by species from inland fisheries.

Year	Production by species (mt)					
	Tilapias	Carps	Charal*	White fish*	Catfish*	Bass*
1982	30,507	5,759	4,898	535	1,563	245
1983	57,558	7,235	5,590	290	1,317	1,324
1984	63,569	10,088	7,890	230	1,793	1,746
1985	53,724	16,549	7,395	285	1,565	1,564
1986	65,568	20,921	7,728	333	2,786	1,224
1987	75,093	26,170	7,800	127	2,366	1,290
1988	74,843	27,056	7,522	95	2,754	1,466
1989	76,575	25,881	5,707	40	2,623	1,968

* Native species

Before 1970, the fisheries of inland waters were based on the exploitation of populations of common carp, native atherinids of the genus *Chirostoma*, and other less important species. Subsequently, however, the seeding of large reservoirs with tilapia fingerlings has resulted in the establishment of tilapia as the most important species in inland waters at present. The country's 24 reservoirs with a surface area of 10,000 ha or larger, do not have tilapia fisheries; in the other 22, tilapia is either the major species or an important component of fish catch. Small and medium-sized dams are regularly restocked with fingerlings produced in hatcheries.

The growth in freshwater fish production has outpaced that of the other animal products used for human consumption (Fig. 4). This may be due to the fact that fish produced in dams, with the exception of *pescado blanco* (*Chirostoma esta*), rainbow trout (*Onchorhynchus mykiss*), and other species which are produced in relatively small quantities, are popular in the rural and urban areas because of their low prices in the markets. For example, tilapia sells at US$2.16/kg while beef sells at US$6-6.60/kg.

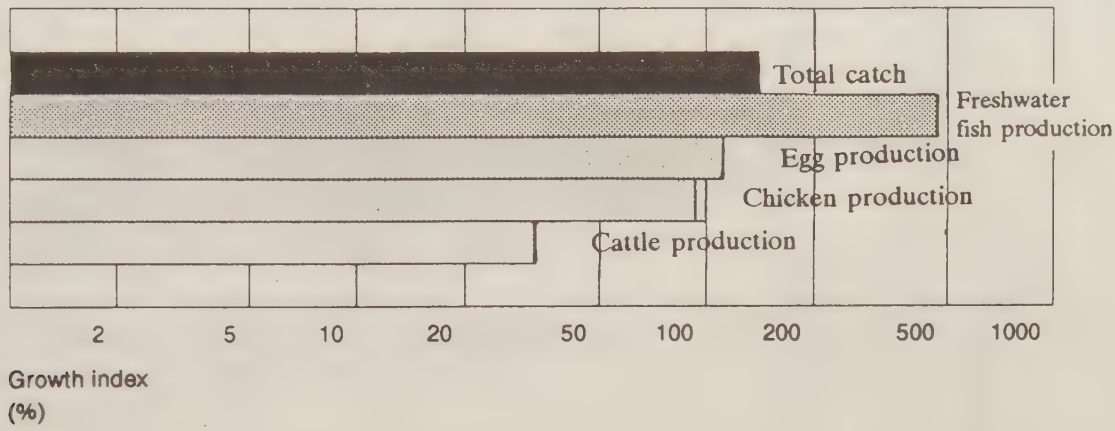

Fig. 4. Growth of freshwater fish production as compared to that of other animal products for direct human consumption.

6.2.5 Fisheries in Major Reservoirs and Lakes

(i) Production

Of the 24 major reservoirs and lakes in the country, nine contribute 21.3 per cent of total freshwater fishery production. In seven of these, the tilapia fishery is the main fishery (Table 13).

In the Chapala, Cuitzeo, Catemaco, and Patzcuaro lakes where there is a higher fish species diversity, tilapia contribute less to the fishery production than in reservoirs (Table 13). In lakes Cuitzeo and Chapala, the data indicate the displacement of the native species like *Chirostoma* (*charales*) and white fish by the exotic tilapias.

The present situation in these nine water bodies varies from one to the other; in all nine dams, however, there are environmental and/or social problems that require greater attention.

Table 13

Tilapia contribution to the fishery production of nine major reservoirs and lakes of Mexico

Dam			Production			
Name	Area (ha) 1/	Basin	Total production (mt) 2/	Contribution to national aquaculture production 3/	Main fishery	
					Species	Contribution (%) to total fishery in lake 4/
1. Lago de Chapala	83,850	Rio Lerma	8,590.4	5.9	Tilapia	40.6
2. Lago de Cuitzeo	42,076	Rio Lerma 5/	673.8	0.4	Tilapia	34.6
3. Lago de Catemaco	6,770	R. Papaloapan	1,884.2	1.3	Tilapia	37.6
4. Lago de Patzcuaro	13,000	R. Lerma 5/	1,566.4	1.0	Carp	17.9
5. Presa El Infiernillo	27,300	R. Balsas	13,579.9	9.3	Tilapia	87.8
6. Presa Malpaso	25,120	R. Grijalva	147.7	0.1	Tenguayaca 6/	98.0
7. Presa La Angostura	37,885	R. Grijalva	3,409.1	2.3	Tilapia	97.6
8. Presa Vicente Guerrero	34,979	R. Purificac	376.8	0.2	Tilapia	35.5
9. Presa Temascal	30,757	R. Papaloapan	1,238.7	0.8	Tilapia	94.0

1/ Mean value for 10 years

2/ Mean value, 1980–1989

3/ In comparison with national aquaculture production, mean value during the period 1980–1989

4/ Obtained value considering 1989 production

5/ Lakes with closed basin into Lerma River's basin

6/ Native species (Cichlasoma urophtalmus)

In the Chapala and Cuitzeo lakes and in Infiernillo and Angostura reservoirs, the situation is one of overexploitation, as confirmed in recent investigations by the authors of this paper. The fisheries at Patzcuaro and Catemaco lakes and in Vicente Guerrero and Malpaso reservoirs is underexploited; in Temascal reservoir, the fisheries is in equilibrium (Table 14).

Table 14
Current fisheries in nine reservoirs and lakes in Mexico

Water body	Current yield (kg/ha)	Potential yield 1/ (kg/ha)	Yield RMS (kg/ha)	Effort		
				Current	Optimum	Unit
Infiernillo	815.0	60-120 1/	649.9	28,442	17,680	Gill net
Chapala	146.0	40-60	113.0	29,689	13,560	Gill net
Angostura	84.9	80-90	123.0	9,440	2,412	Gill net
Patzcuaro 2/	178.3	100-230	203.0	1,051	2/	nd
Catemaco	276.0	50-60 1/	340.0	nd	nd	nd
Cuitzeo	9.5	>425 1/	9.9	nd	nd	nd
Temascal	41.8	36-69	36.6	247	245	Fishermen
V. Guerrero 2/	8.1	66-138	37.1	91	nd	Boat
Malpaso	8.8	36-68	10.4	554	604	Gill net

1/ Not adjustable to the Morphoedaphic Index (MEI)
2/ Fisheries in process of development
nd = no data

The fisheries in Patzcuaro and Michoacan lakes has been affected by the introduction of many exotic species including black bass (*Micropterus salmoides*), common carp (*C. carpio*), grass carp (*Ctenopharyngodon idella*), and tilapia (*O. niloticus*), with the economically important indigenous species having been displaced by the introduced species.

Cuitzeo lake has salinity and siltation problems that have resulted in low fishery yields. Chapala lake, Mexico's biggest, is also facing serious problems in its hydrology and water quality, which makes it behave more like a reservoir than a natural lake. These water bodies are in need of a sound overall management to promote the optimal utilization of the resource.

(ii) Employment Opportunities

The inland fisheries sector employs more than 11,500 fishermen representing 7.3 per cent of the country's total fishermen. The distribution of fishermen does not seem to be correlated with fish yields from a lake; rather, it seems to be related more to tradition and to the lack of opportunities in other economic activities. For example, in the intensively fished Patzcuaro lake, the index is 6.2 ha/fisherman and the yield is 1.1 mt/yr/fisherman. In contrast, El Infiernillo reservoir has an index of 10.3 ha/fisherman and a yield of 7.4 mt/yr/fisherman. The indices show the high fishing intensity in some dams and the low economic yield in others. Patzcuaro lake is a good example of lake with low productivity where high fishing effort results in very low yields. On the other extreme, El Infiernillo exemplifies a reservoir where high yields per fisherman are obtained even with high fishing intensity (see Table 15).

Table 15
Fishing intensity and yield in nine major reservoirs and lakes of Mexico

Water body	Fishing intensity index (ha/fisherman)	Yield (mt/yr/fisherman)
Vicente Guerrero	264.9	4.2
Temascal	124.5	5.9
Malpaso	89.7	0.9
Cuitzeo	44.9	2.2
Chapala	38.1	5.1
Angostura	26.2	1.1
Catemaco	26.2	1.4
Infiernillo	10.3	7.4
Patzcuaro	6.2	1.1

The fishermen are organized in legally recognized associations which assures them of certain benefits (e.g., access to credit). The average age of fishermen is between 31.1 yrs (Chapala Lake) and 42.8 yrs (Cuitzeo Lake). More than 60 per cent of the fishermen are from cities close to the reservoirs and lakes. The economic dependence on fishing is higher where job opportunities are found only in fisheries, as in El Infiernillo reservoir, and lower in areas where other options are available, as in Vicente Guerrero reservoir.

(iii) **Economic Aspects**

Fish produced in the reservoirs and lakes, mainly tilapia, are sold beyond regional boundaries and reach the three major cities in the country.

More than 65,000 people comprise the fishery communities at the nine reservoirs and lakes listed in Table 15, with economic conditions varying depending on the benefits obtained from the fisheries. In three cases (El Infiernillo, Temascal, and Malpaso), low buying prices for fish tend to discourage the fishermen from increasing their catch.

Tilapia sells at a very low price of US$0.33/kg at El Infiernillo reservoir which has a high fish production. The absence of value-adding facilities at the reservoir or lake and the presence of a large number of brokers involved in fish marketing, do not help either.

To improve fish marketability, the Government has provided financial assistance in the form of covering the total cost of production and distribution of fingerlings for restocking or through covering the total cost of setting up the minimum requirement for support infrastructure. In the latter case, the lack of planning with respect to infrastructure development has led to the construction being of no use to the fishermen.

(iv) Production Potential

The morphoedaphic index (MEI) is the most commonly used model to predict the production potential of reservoirs and lakes in Mexico. However, it still needs to be adapted to Mexican conditions.

Earlier estimates give a potential yield of 100 kg/ha (Henderson, 1974; Cadena *et al.*, 1979; Vidal, 1984). In the nine major reservoirs and lakes, these limits have been reached.

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WORKSHOP SUMMARY

Recognizing the need for a review of the status of the tilapia capture fisheries in the IPFC Region in view of their considerable importance in some countries, the Fourth Session of the Working Party in Kathmandu, Nepal in 1988 recommended that this topic be made the subject of a workshop to be held in conjunction with the Fifth Session held during 27-29 June 1991. Dr. Arun Jhingran, Director of the Central Inland Capture Fisheries Research Institute, Barrackpore, West Bengal, India, was elected Chairman.

The 1990 FAO Yearbook of Fisheries Statistics (Catches and Landings) and the 1990 FAO Fisheries Circular No. 815 (Rev. 2) on aquaculture production give production figures of 260,223 and 179,667 mt, respectively, for capture fisheries and aquaculture for countries of Asia and the Pacific in 1988, as shown below:

	Capture Fisheries (mt)	Aquaculture (mt)
O. mossambicus	40,849	28,054
O. niloticus	28,120	93,749
O. spilurus		28
Tilapias not identified	191,254	57,864
Total	**260,223**	**179,667**

When compared with cyprinid production in Asia (excluding China) of 371,386 mt and 221,759 mt for capture fisheries and aquaculture, respectively, it can be said that the tilapias have been performing quite well vis-a-vis the cyprinids in the Region. The inclusion of China would change the total picture, though, as cyprinid production in that country is in the order of 3.7 and 3.8 million tons from capture fisheries and aquaculture, respectively, as shown below. As China production is based on the regular stocking of hatchery-produced fingerlings and their efficient harvesting, the same figures are included under aquaculture in both statistical yearbooks. The difference is due to the absence of the production of 117,000 mt for black carp, which is not included in the yearbook of capture fisheries.

	Cichlids	Cyprinids
	ASIA (with China)	
CF	306,329	4,112,186
A	181,985	4,080,259

CHINA

CF	39,000	3,740,800
A	39,000	3,858,500

ASIA (without China)

CF	267,329	371,386
A	142,985	221,759

where CF = capture fisheries and A = aquaculture.

Australia traditionally relies on marine fisheries resources, with freshwater production contributing less than two per cent to the country's total. Also, as alternative sources of animal protein are readily available, there is little demand for freshwater fish for food. Lacking any real demand for the fish as food or other resources, the importation of tilapias into Australia has been banned. Their culture is either prohibited or discouraged in all states except Tasmania (Bluhdorn). Fisheries authorities have been trying to control populations of *Oreochromis mossambicus* that have become established in Queensland and Western Australia, although overseas experience shows that this is likely to be exceedingly difficult, if not impossible. There is a growing concern in Australia on the potential impacts of *O. mossambicus* on the indigenous species although no exact information is available. It was pointed out during the discussion that management decisions such as those taken in Australia rest on a number of information inputs and that biological evidence should be weighed along with management needs, economic benefits, and political considerations. Based on the impacts of earlier introductions of terrestrial and aquatic organisms in the country, prudence dictates that tilapia not be encouraged in Australia.

O. mossambicus and *O. niloticus* were introduced into **Bangladesh** from Thailand in 1954 and 1974, respectively (Rahman). Unlike the other countries in the Region, though, tilapia landings in Bangladesh have been rather insignificant compared to total fish production, and came mainly from catches in Kaptai reservoir, from small seasonal ditches, sewage-fed ponds and lakes and from brackishwater creeks and canals. Tilapia is also harvested from freshwater ponds as well as from brackishwater shrimp ponds where they are accidental entries.

While good statistical data are lacking, yields from tilapia capture fisheries in Kaptai reservoir have been estimated at 2,890 mt in 1989-90. The small seasonal ditches gave yields of 1,000-1,800 kg/ha in 3-5 months and 11 sewage-fed ponds near Dhaka were reported to have produced five mt/ha/yr. DOF estimates that a total of 1,643 mt of tilapia was produced from approximately 147,000 ha of freshwater ponds in the country and another 1,069 mt from some 100,000 ha of coastal shrimp farms.

Tilapia is considered a potentially good species for culture in view of its ease of rearing, low cost of production, and good profit margins. However, the consumers are not as yet accustomed to its taste and much still remains to be done before the fish is widely accepted in the country.

In India, there is no other species of fish that has generated so much controversy as tilapia (Jhingran). In the early stages of the country's inland fisheries development, it was considered prudent to introduce exotic species like *O. mossambicus* which adapted well, bred profusely, subsisted on a variety of food under diverse ecological situations, and contributed substantially to national fish production. Since then, however, the long-term performance of the fish in some of India's waters as well as its biological plasticity have posed a series of questions on its desirability in waters which harbour a rich and highly diverse native ichthyofauna. While its capability to make a sizeable contribution to total fish yield remains unquestionable, the argument for and against the species centres more around its impact on the co-existing endemic fauna. In the absence of in-depth biological investigations on the species in the Indian context, doubts raised about the species still remain unanswered.

Nevertheless, tilapias have been stocked in a number of South Indian reservoirs with varying results and in brackishwater impoundments of West Bengal. For example, tilapia production in Tamil Nadu reservoirs is higher in smaller reservoirs (<50 ha) at about 101.5 kg/ha as compared to that in large reservoirs (>10.000 ha) which gave yields of only 0.14 kg/ha. The average tilapia yield in 45 reservoirs was a low 7.8 kg/ha.

It was noted that tilapia is utilized in reservoirs with high densities of blue-green algae which the fish is able to digest. It was also mentioned that *O. niloticus* has a better market acceptance than *O. mossambicus*.

It has been observed that the initial surge in tilapia numbers was often followed by a drop almost simultaneous to an increase in carp populations. It was suggested during the discussion that there is a need to develop productivity models relating to reservoir size, carp numbers, tilapia numbers, and other parameters.

In Indonesia, tilapia fisheries produced 57,245 mt in 1988, representing eight per cent of inland fisheries production (Hardjamulia). Of this volume, 7,980 mt were caught from open waters while 49,265 mt were produced in both fresh- and brackishwater culture activities. Tilapia are caught in rivers in Java, but not in Kalimantan or Sumatra, and harvested from milkfish and shrimp ponds where they constitute an "extra crop". Intensive tilapia culture in floating cages in reservoirs has also been recently started.

As in India, *O. niloticus* is preferred to *O. mossambicus* and is a cheap source of animal protein for the lower-income groups, especially those far from the sea.

Where there is competition over the water resources, intensive culture of *O. niloticus* and red tilapia may be required in Indonesia, and is likely to take the form of floating cage culture as has already been applied in some reservoirs. In the future, it is planned to stock tilapia only in closed systems, i.e., lakes and reservoirs.

In **Papua New Guinea** (PNG), the tilapia fishery is based entirely on *Oreochromis mossambicus* which was brought into the country in the late 1950s (Coates). It is in the Sepik/Ramu River basin in the northern part of the country where the species has become important in the capture fishery, yielding 3-5 mt/year and contributing about half of the artisanal/subsistence catch in the area. At present, *O. mossambicus* is the most important fish species in PNG, including marine species (except tuna which is largely taken out of the country by foreign fishing fleets).

The success of *O. mossambicus* in PNG may be attributed to the lack of predators that prey on it and to its detritivorous habit that enabled it to occupy a vacant ecological niche, there being no known detritivores among the native species. Moreover, it appears less susceptible to disease unlike the native species which have been shown to carry heavy parasitic loads. There are also no known cases of *O. mossambicus* causing the extinction of native species despite its dominance in fish catches for over 25 years now.

At present, the PNG tilapia fishery is not managed directly except for the stocking of the river basin with *Tilapia rendalli*, a macrophyte feeder selected for a number of reasons including the following: (i) ease of handling and breeding; (ii) ability to obtain stocks of known genetic origin; and (iii) ability to obtain stocks quarantined at source. Its performance vis-a-vis the common carp cannot be compared at the moment considering that the common carp contribute significantly to the fishery in the future.

Sri Lanka is another country in the Region where the inland fish production is mainly based on the exotic tilapias *O. mossambicus* and *O. niloticus* (Amarasinghe and De Silva). Prior to their introduction into Sri Lanka reservoirs, fish production was very low, which was believed to be due to the lack of lacustrine or lacustrine-adapted species among the indigenous fish fauna. Their successful establishment in reservoirs, as manifested by significant contributions ranging from 56 to 99 per cent of total landings, has been attributed to the highly favourable environments in the reservoirs and to their ability to utilize the blue-green algae abundant in the water.

In contrast, the contribution of exotic carps to the reservoir fishery in Sri Lanka has been insignificant, probably on account of a number of reasons. First, all the introduced carps are sub-tropical and none of them, except for *Cyprinus carpio*, has established breeding populations in the reservoirs. Secondly, stocking-recapture fisheries successfully practised in some countries like China, has not been scientifically planned in Sri Lanka and has therefore not given good results. Thirdly, there is an inadequate supply of carp fingerlings of the right size for stocking in the reservoirs; thus, stocking densities are appreciably higher, as in medium-sized reservoirs of less than 1,000 ha in

area, the benefits of stocking-recapture fishing have to be carefully evaluated against alternative methods of increasing fish yields in inland waters, such as development of culture-based fisheries in seasonal tanks.

The inland culture fishery, be it cichlid- or cyprinid-based, is not well developed in Sri Lanka. Where practised, tilapia yields from ponds range from 200 to 500 kg/ha. Carp is grown in polyculture in ponds but no figures are available as to its economic feasibility. There is evidence to suggest that there are apparent synergistic effects of tilapias and cyprinids, with the presence of tilapias possibly important for increasing overall yields.

No detrimental effects of introduced cichlids have been reported in Sri Lanka and with their high consumer preference, they are likely to remain the most important fish group in the country's inland fisheries development.

In the **Philippines**, tilapia is the most extensively used finfish in inland waters where it is either stocked in open waters or cultured in cages and ponds (Baluyut). *O. niloticus* is the most preferred species for stocking and culture although other species are available locally (e.g., *O. mossambicus, O. aureus, T. zillii*) and hybridization trials are continuing to develop new and better strains such as red tilapia hybrids. In 1989, a total of about 102,000 mt of tilapia was produced in the country, of which about 20,000 mt were caught from the wild and about 82,000 mt were harvested from aquaculture. Tilapia freshwater capture production represents about nine per cent of the country's total production of about 200,000 mt from inland fish capture; it contributed about 13 per cent to the total aquaculture production of about 630,000 mt. Most of the tilapia production from aquaculture comes from the fish cages in Region IV, where Laguna de Bay and other smaller lakes are located.

Tilapia cage culture in the Philippines started in 1967, expanded rapidly and reached its peak of 1,000 ha in Laguna de Bay in 1983. Since then, it has somehow declined in importance, with the areal coverage in Laguna Lake estimated to be just about 260 ha at present.

In **Thailand**, tilapia has been contributing quite significantly to inland fish production since 1983, with yields ranging from 2,500 mt in 1983 to 13,600 mt in 1984 (Pawaputanon). Annual average production for the period 1983-1988 was 6,730 mt, lower than that for *Puntius* (10,530 mt) and *Channa* (13,650 mt), the two most common fish in Thai reservoirs.

O. niloticus is the most common species harvested from village ponds in the country, accounting for 20.68 per cent of total catch from such ponds in 1986. Large reservoirs whose surface areas exceed 1,000 ha are believed to have high potential for tilapia production as considerable quantities have been observed from the catch landings, although accurate statistics are not available. This potential lies in the ability of the fish to establish populations within a reservoir on account of its natural reproductive ability, thus eliminating the need for regular stocking of fingerlings.

Quantified historical data on tilapia introductions and stocking in the inland waters of **Malaysia** are poor (Yap). The FAO Fishery Statistics Yearbook for 1988 gives a yield of 3,346 t, of which *O. mossambicus* represented 2,350 t. Thus, tilapias contributed about 20 per cent to the total inland fisheries catch whereas the cyprinids contributed perhaps 60 per cent of the total catch of 16,252 t in 1988. In cage culture, *O. niloticus* accounted for 73.4 per cent of the total cage production while red tilapia accounted for 8.2 per cent. At present, large numbers of Nile tilapia and red tilapia are stocked into reservoirs and rivers. In 1988, 27.4 per cent of nile tilapia and 14.2 per cent of red tilapia seed produced in government hatcheries in Peninsular Malaysia were released into public water bodies. *O. mossambicus* is stocked in recreational water bodies for sport fishery and into sewage oxidation ponds where it serves as biological filter.

A regional analysis of the tilapia fishery, prepared for the countries of **Latin America** by Juares-Palacios, was presented for comparison with the experience available in the IPFC Region. In a number of countries in Latin America, tilapia is either in the early stages of being established or has not yet become established in open waters such as reservoirs and lakes. Three countries in Latin America (viz., Cuba, Brazil, and Mexico) are well-advanced in their management of reservoir fisheries in which tilapias figure prominently.

Cuba started stocking its reservoirs with tilapia in the late 1970s. *O. aureus* is now the most important species in the catches (with 14.9 mt landed in 1988), followed by *T. rendalli*, common carp, and black bass (*Micropterus salmoides*). The systematic seeding of reservoirs and the increased efficiency of fishing techniques and fisheries management have led to a sustainable growth in inland fisheries, which is based largely on tilapias. The largest reservoir, Zaza (11,400 ha), had an average fish yield of 95.5 kg/ha/yr for the 1984-1988 period; 15 other Cuban reservoirs had average fish yields ranging from 11.5 to 297.2 kg/ha/yr. Capture limits are established on the basis of the following: morphoedaphic index; historical capture series and efforts analysis; relation between capture per unit area and phytoplankton density; and prediction model application.

The highest number of small reservoirs (dams) (about 60,000) in Latin America is found in **Brazil**, specifically in the northeast where an average production of about 17,088 mt was recorded from 1979-1989 representing 8.1 per cent of the total freshwater fisheries of Brazil. *O. niloticus*, a favoured exotic introduced into the country in 1971, dominates the catches. From 1980 to 1988, it has consistently topped the list of species landed, followed by the local *Plagioscion squamosissimus* and *Cichla ocellaris*. The exotic tilapias contributed from 75.2 to 81.1 per cent of the total landings in the same period. Stocking material is produced in seven fisheries stations in the Region.

Among the measures recommended for increasing fish production is the eradication of the carnivorous species *Serrasalmus rhombeus* (piranha) and *S. natereri* (pirambeba) using chemical methods.

In Mexico, reservoirs have been stocked with tilapia and common carp. Tilapias are widely accepted in the rural areas and among lower-income urban and suburban populations.

In the period 1979-1989, fisheries production from inland waters grew by 475 per cent, largely as a result of fish introductions and stocking. Statistics available for fisheries production from major dams show a sustainable rapid increase from 43,507 mt in 1982 to 123,000 mt in 1989. Four exotic fish species (i.e., *O. aureus, O. niloticus, O. mossambicus*, and *Cyprinus carpio*) dominate the catches. In 1989, production for each species was as follows: tilapias, 76,575 mt; common carp, 25,881 mt; and *Chirostoma* spp. (native fish species), 5,707 mt. In nine reservoirs, the fishery yield ranged from 8.1 to 815 kg/ha/yr.

Using predictive yield models, it is believed that the fishery potential of large dams is now largely fully utilized, while there is further possibility for expansion of fisheries in smaller reservoirs. In those reservoirs with substantial changes in water level and higher salinities, fish production potential is expectedly low.

Summary

In most tropical and subtropical countries of the Region, tilapias contribute in varying degrees to fish production. They are dominant or prominent both in inland capture as well as in culture-enhanced fisheries in Sri Lanka, Papua New Guinea, Philippines, Indonesia, and some parts of India.

O. mossambicus is the first tilapia species introduced into most countries of the Region and has formed the basis for capture fishery in some countries. It was only after the superior quality of *O. niloticus* was tested under aquaculture conditions that it was introduced into culture-based fisheries and, in the case of Thailand, also stocked in reservoirs. Both *O. mossambicus* and *O. niloticus* are doing well in reservoirs of medium or high productivity. More recently, there has been a trend towards replacing *O. mossambicus* with *O. niloticus* in some water bodies of the Region. Such management is based on the knowledge that *O. niloticus* has a faster growth rate, does not develop stunted populations as readily as *O. mossambicus*, and is considered to have a better-quality flesh.

Experimentation with crossbreeding of *O. mossambicus* and *O. niloticus* has shown that hybrids are faster growing. Where both species are present in the same water body, such crossbreeding occurs naturally. In the Philippines, there is hardly any pure strain of *O. mossambicus* present in natural water bodies, although *O. mossambicus* was the first tilapia species to be introduced into that country.

Some problems of declining yield of tilapia in capture fisheries exist usually as the result of overexploitation, unsuitable habitats, and perhaps hybrid introgression. Uncontrolled developments in the catchments of some water bodies have also resulted in decreases in yields. Fishery management techniques could overcome many of these problems and should address the increasing and varying demands on the aquatic resource itself.

The uncontrolled expansion of cage and pen culture in some water bodies has led to the deterioration of water quality and has made both open water fish stocks and those held in cages and pens vulnerable to fish diseases. In extreme situations, this could lead to a drastic, sometimes catastrophic, downturn in fish production. The Working Party recognized the need for a detailed analysis of such situation and for guidelines and criteria for maintaining sustainable and well-balanced development of cage and pen aquaculture and capture fisheries for the same water bodies. The forthcoming symposium on the sustainable development of inland capture and culture-enhanced fisheries in the IPFC region, programmed for 1993, is expected to discuss this subject in more detail.

The improvement of fish yields and fish quality through the introduction of *O. niloticus* in some water bodies with established populations of *O. mossambicus*, was discussed. The Working Party noted that *O. mossambicus* is performing well in some open water bodies in the Region (e.g., Sri Lankan reservoirs and Sepik River in PNG). It also noted that data on the superior performance of *O. niloticus* relates mainly to culture situations and may not be directly applicable to capture fisheries.

It was concluded that tilapias constitute an important protein source in many countries in the Region where they have found growing acceptance not only among the low-income groups but also among the more sophisticated urban and upscale markets. While their introduction into a number of water bodies has been justified, the Working Party strongly felt that further studies need to be undertaken to determine the impacts of tilapia introductions on the native species in lakes and reservoirs in the Region. The Working Party also expressed concern about the genetic purity of tilapia strains for future introductions and stocking. It was suggested that the Secretariat explore the possibility of collaboration with ICLARM in this area.

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